BWD ELECTRONICS

603B MINI-LAB

INSTRUCTION MANUAL

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BWD ELECTRONICS

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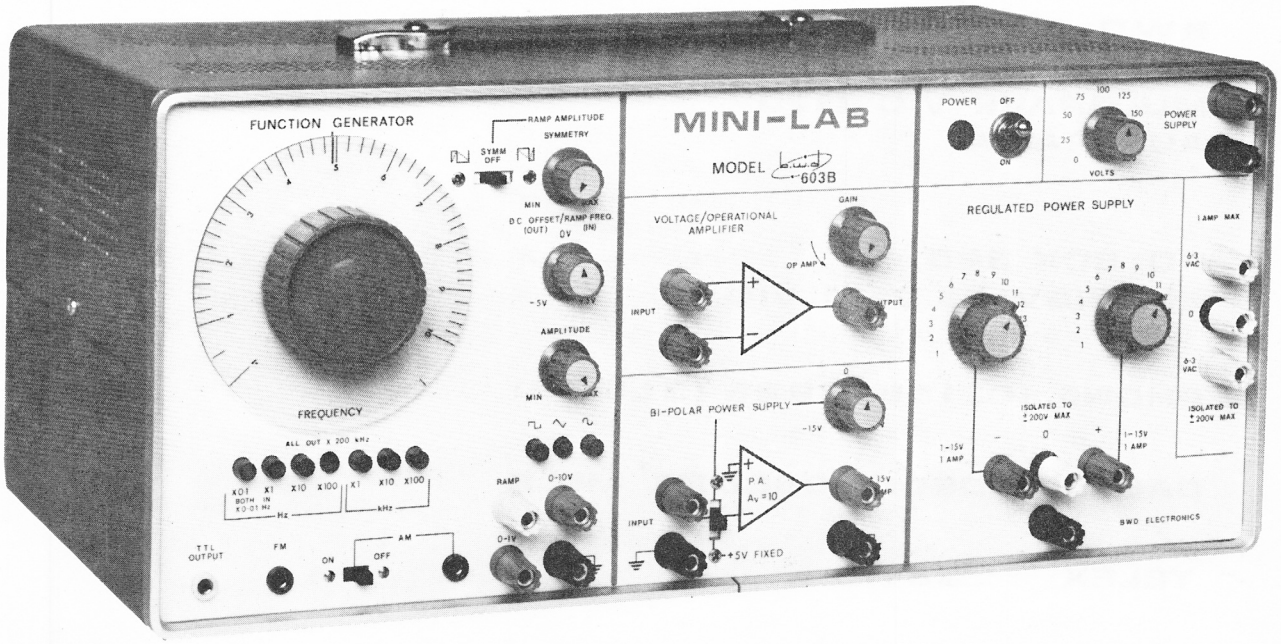
ISSUE 7



BWD 603B
MINI-LAB

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INSTRUMENT HANDBOOK

MODEL BWD 603B MINI-LAB

1. GENERAL:

The MINI-LAB provides seven independent instruments in a single compact cabinet for use in the laboratory or classroom to supply signals and power for a wide range of measurements and experiments in the fields of electronics, chemistry and bio-medical engineering.

The functions available include:-

(a) Sine, square, triangle, pulse and ramp generator with variable symmetry and D.C. offset controls producing a wide variety of waveforms from 0.001Hz to 1MHz which can be amplitude and frequency modulated by an external signal.

(b) A ramp generator 5 sec to 50m sec.

(c) A switched power amplifier/bi-polar power supply combination.

(d) An operational Amplifier with variable gain.

(e) Two variable power supplies 1-15V and 1+15V at 1 Ampere output.

(f) A 0►+ 200V variable power supply.

(g) A centre tapped 12.6V A.C. supply, and

(h) Numerous instrument combinations by link interconnection.

2. PERFORMANCE:

Function Generator:

2.1 Waveform: Sine, triangle or square, pulse and ramp with amplitude or frequency modulation.

2.2 Frequency range: 8 Decade ranges calibrated from 0.01Hz to 1MHz plus a 200kHz to 2MHz range. An additional uncalibrated section of the dial extends range to 0.001Hz. Dial covers 2 decades on each range.

Calibration: ± 3% of full scale 10Hz - 1MHz.

2.3 Voltage output: Two simultaneous levels 10 volts p-p open circuit, 5 volts p-p into 600Ω.
1 volt p-p open circuit, 0.5 volts p-p into 600Ω.

Variable output provides continuous control of > 100:1 of both outputs whilst maintaining a constant 600Ω output impedance. Outputs, overvoltage and short circuit proof.
Output level: Less than ±2% level variation over calibrated frequency range into 600Ω ± 5% between 1 and 2MHz.

2.4 Output offset: Output normally centered symmetrically about ground. Push pull switch applies a continuously variable 0 to ± 5 volts offset voltage. Control also doubles as ramp frequency control (see 8 below). NOTE: 0-1V output has ±0.5V offset.

2.5 Symmetry (fixed): ± 2% From 0.01Hz to 1MHz (calibrated portion of dial).
Symmetry (variable): Pulse or ramp waveforms. Continuously variable from 1:1 to over 1:50 or 50:1 by switch selection. Applies to sine, triangle or square waveforms. Variable control also doubles as ramp amplitude (see 8).

2.6 Sine wave distortion: < 1.5% 10Hz to >50kHz <2% at 1MHz (typically 0.6% 20Hz to 20kHz).
Square wave rise time: 100n sec into 600Ω load and <50pf capacitance.
Triangle linearity: > 99% within calibrated range on dial up to 100kHz.
Triangle symmetry: Better than 2% within calibrated range up to 100kHz.

2.7 Frequency modulation: Function generator can be swept over 2 decades by the internal ramp generator or over 4 decades by an external log sweep. It can also be used as an externally programmed oscillator over a 100,00:1 frequency range.
Input: 1 volt dial division.
Input impedance: 10KΩ.
Linearity: 2%.
Input frequency: DC to >10kHz.

2.8 Sweep ramp generator:
Output voltage: 0 to >+10 volts with a continuously adjustable upper limit from +0.6 to +10 volts using the variable symmetry control in the OFF mode.
Ramp duration: >5 sec to 50m sec approximately.
Continuously adjustable by the OFFSET control in the OFF position.

When coupled into the VCO socket the function generator will sweep from the frequency selected by the dial up to the frequency set by the ramp amplitude control. An automatic circuit prevents the sweep exceeding the dial range. Horizontal drive to oscilloscope or recorder is also taken from ramp output via the voltage amplifier (see 14) to set drive voltage and polarity required.

2. PERFORMANCE (continued)

2.9 Amplitude Modulation: 0 to 95% modulation all output waveforms from 0.001Hz to 2MHz.
Input: 4 volts p-p for 90% modulation.
Input resistance: approximately 10KΩ.
Modulation input range: DC to 1MHz. An input voltage may also be used to control the output level remotely from 0.5 to 20 volts p-p. NOTE: Unmodulated carrier output level is 10 volts p-p and 20 volts p-p at peak modulation open circuit. Both AM and FM modulation can be applied simultaneously.

2.10 TTL Output: Identical pulse width to main output. > 3 volts output into 2 TTL inputs. <80n sec rise and fall time.

Selectable Power Source:

2.11 Amplifier
Gain: Voltage, fixed x10. Input 3 volts p-p for 30 volts p-p output maximum.
Current gain approximately x5000.
Input: 10KΩ, inverting input only.
Frequency response: DC to >80kHz at 20 volts p-p into 15Ω.
Rise time: < 5μ sec for ± 10 volts output swing.
Slew rate: 4V/μ sec.
Maximum output: ± 15 volts p-p minimum ± 1 amp p-p current (automatic overload). 7 Watts RMS into 15Ω load. ± 15 volts into>15Ω.
Distortion: <0.1% at 1kHz increasing to <0.5% at 20kHz at full output (± 15 volts into 15Ω).
Hum and noise: 60db below maximum output.
Output impedance: <0.2Ω.

2.12 Bi-Polar power supply
Voltage Range: Continuously variable from + 15 volts through zero to -15 volts.
Current 1 amp maximum at any voltage setting (automatic overload).
Output impedance: <0.2Ω.
Hum and noise: <25mV p-p (5mV RMS) at full output (15 volts at 1 amp).

2.13 Fixed power supply:
Voltage + 5 volts
Current 1 amp with automatic overload
Output impedance: <0.5Ω.
Hum and noise: <25mV p-p at full output (8mV RMS).

Voltage/Operational amplifier:

2.14 Amplifier
Gain: Continuously variable from x1 to x100 approximately.
Input: Balanced 10KΩ each side to ground with gain control in circuit.
Input overvoltage proof.
Frequency response: DC to > 80kHz - 3db at all gain settings.
Slew rate: 4V/μ sec.
Output Impedance: 500Ω (short circuit proof).
Output noise: <5mVRMS at x100 gain.
Input open circuit: 25mV p-p maximum with function generator set to less than 100kHz.

2.15 Operational amplifier
Input 0.5MΩ isolated by switch
Performance characteristics see fig. 2 a and b.

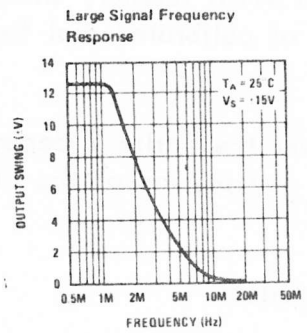


Fig. 2a

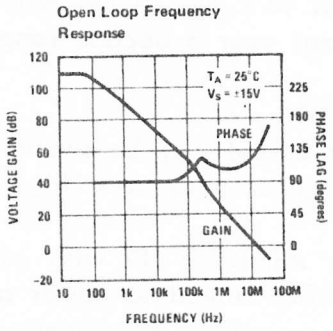


Fig. 2b

Low Voltage Power Supplies:

2.16 Voltage output: Two independent variable outputs with a common but isolated zero line (200 volts DC isolation).
Range + 2 to + 15 volts and -2 to - 15 volts or a single ± 4 to 30 volts.
Current output: 1 amp maximum each output. Constant current overload.
Regulation: 1% for 10% line change, or 0 to 1 amp load change.
(Typically <0.5%).
Hum and noise: <5mVRMS at full load.
NOTE: Minimum voltage approximately 1V to 2V.

High Voltage Power Supply:

2.17 Voltage and current 0 to ± 200 volts DC. 30m amp available at 175 volts, 20m amps at 200 volts. Constant current overload at approximately 40m amp. Output referred to ground.
Regulation: 1% for 10% line change or 0 to 30m amp load change measured at 150 volt output.
Hum and noise: <25mV RMS at full output.

AC Supply:

2.18 Voltage and current 6.3 volts to 0 to 6.3 volts 1 amp each side. Completely isolated and each 6.3 volt leg is separately fused.

Facilities by Interconnection:

2.19 Power Waveform Output (1 with 12)
Function generator linked to power amplifier.
Frequency range: 0.001Hz to >80kHz.
Output: 0-30 volt p-p with 1 amp capability. Output may be symmetrical or offset about ground to ± 15 volt p-p (minimum).

2.20 A.M. Modulation at Line Frequency. (9 with 18).
With 6.3Volt AC supply linked to A.M. input via a 39KΩ resistor, sine output will be 90% approximately A.M. modulated. Carrier output range 0.001Hz to 2MHz.

2. PERFORMANCE (continued)

2.21 F.M. Modulation at Line Frequency (7 with 18)
Linked as for A.M. but to F.M. socket with a 39KΩ resistor, sine, square or triangle will be swept over a decade range of calibrated dial frequency.

2.22 Swept Output (7 with 8)
The function generator output may be swept over the entire 2 decade range of the dial on any range or down to <10% of any portion of the dial.

2.23 High Sensitivity Power Amplifier (12 with 14)
With operational amplifier linked to power amplifier.
Output: As for power amplifier specification.
Voltage gain: Continuously variable from x10 to x1000.
Frequency response: DC to > 20kHz.

2.24 Function Generator Op Amp Link (1 with 10)
Push-pull signals: With generator output linked to inverting input a signal 180° out of phase with the generator is obtained to frequencies >80kHz.
± Pulse output: Sharp pulses to >100kHz can be generated by over-driving the op-amp with offset triangular waveforms. Rise time is controlled by degree of overdrive and op-amp gain. Other waveforms such as half sine, log curves, truncated triangular and complex shapes of almost infinite variety can be obtained by combining the wide range of facilities provided.

2.25 Power Supply: ± 45 volt 1 amp (11 with 16)
By linking the -15 volt output to the bipolar output, output voltages to +45 volts can be set. By connecting the +15 volt output to the bi-polar supply voltages to -45 volts can be set.

2.26 Modulated Power Supply. ± 45 volt 1 amp (1 and 11 with 16)
If the bipolar supply is switched to power amplifier and its input linked to the function generator the low voltage supply can rise on top of the amplifier output at low frequencies to provide for example, simulated power line ripple.

2.27 Other facilities
Facilities such as voice modulated signals, complex waveforms and many experiments and measurements are described in the comprehensive handbook provided with each instrument.

General Details:

2.28 Power requirements:
95 to 135 volts)
190 to 265 volts) 50 - 60Hz, By switch selection (rear panel).

2.29 Finish: Light coloured panels and sage green vinyl coated aluminium covers with anodised aluminium surrounds.

2.30 Warranty: The instrument is guaranteed for a period of twelve (12) months against faulty materials and workmanship.

2.31 Dimensions: 420mm (16½") wide x 200mm (8") high x 260mm (10-1/4") deep. Overall knobs, etc.

2. PERFORMANCE (continued)

General Details (Cont'd)

2.32 Weight: 10kg (21 lbs) net , 11kg (24 lbs) packed.

2.33 Safety Standards: This instrument is designed to closely conform to IEC348 recommendations.

2.34 Ordering Code: BWD 603B.
Accessories:
Dust cover Part No. D28

For full range of accessories suitable for educational experiments, see separate list of 600 accessories.

2.35 Additional Products:

Oscilloscopes: A wide range of instruments are manufactured by BWD Electronics from single channel 6MHz to dual trace 100MHz oscilloscopes including storage oscilloscopes to display, measure or store your MINI-LAB waveforms.

600 Series Accessories:

600A DC - AC 2 pole motor/generator with commutator, slip rings and permanent magnet.

600B Electromagnet with 1 metre leads and 19mm square 75mm long pole piece.

600C 24V lamp mounted with leads and plugs.

600D Microphone with 1 metre screened lead and input plugs.

600E Interconnecting leads, 1 metre long, fitted with 4mm stacking plugs.

600F 7 Pin valve base on stand. Complete with 6AU6 valve.

600G Transistor mounted on stand. Complete with 2N3054 silicon NPN power transistor.

600H 4 Silicon diodes (2 amp). Diodes type BYX21-200.

600I 4kHz - 2MHz parallel resonant circuit and detector diode.

600J Cadmium sulphide cell with variable aperture light shield.

600K 6V buzzer mounted on stand. AC or DC operation.

600L R.C. charging circuit. Time constant 1 sec.

600M L.C. charging circuit. Time constant 1 sec.

600N 30Ω 100mm loud speaker on stand.

2. PERFORMANCE (continued)

600 Series Accessories (continued)

600P C.L. & R phase and impedance circuit.

600Q Low voltage relay with change over contacts.

600Z Lined wooden carrying case.

These are but a sample of the wide range of accessories available for educational fields in electronics and electrical engineering from BWD ELECTRONICS PTY. LTD.

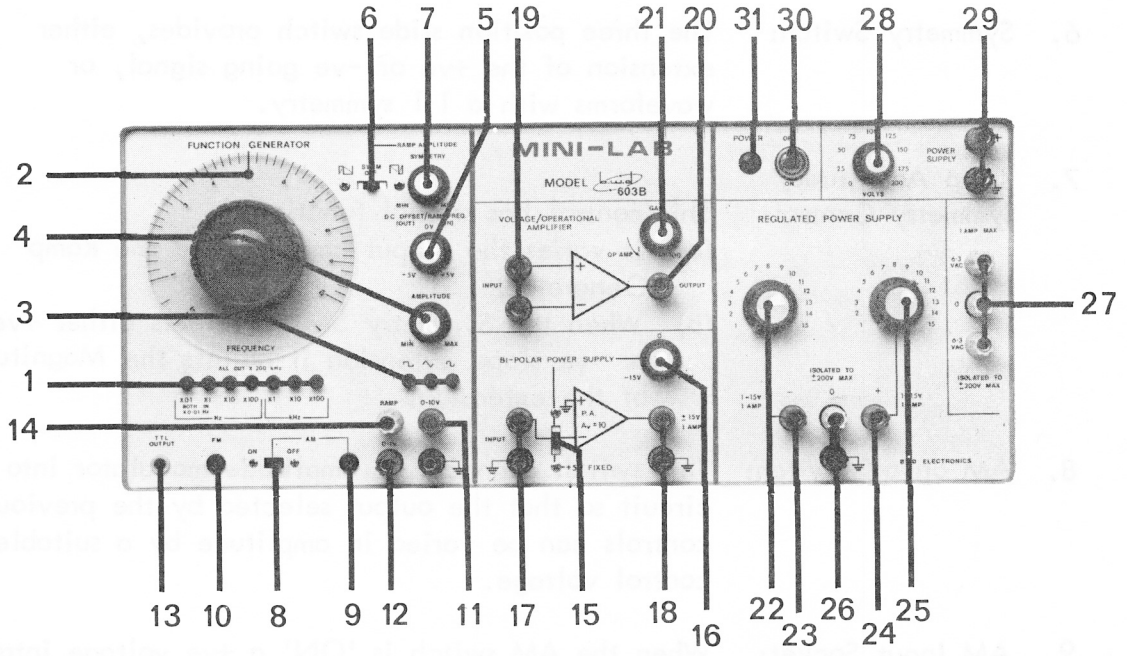
3. CONTROLS AND THEIR FUNCTIONS:

The front panel is divided into three major sections:-

3.1 Signal Source, comprising of a function generator, pulse output, amplitude modulator and a ramp generator.

3.2 Amplifier section, containing a switchable Power Amplifier/Bi Polar Power Supply, and a switchable Voltage/Operational Amplifier.

3.3 Power Supply section, containing three independently variable power supplies and one AC source at line frequency.



3.4 Signal Source Controls.

1. Frequency Range Switch: Desired frequency range can be obtained by depressing the correct button. When the x0.1 and x1 buttons are depressed simultaneously the resultant frequency is x0.01 and with all buttons out x200kHz.

2. Frequency Dial: Calibrated from 1 to 10 with an additional 0.1 marking and is used in conjunction with the Frequency Range Switch to set the output frequency.

3. CONTROLS AND THEIR FUNCTIONS (continued)

3.4 Signal Source Controls: (cont'd)

3. Function Selector: Three outputs are available by selection of the correct button, sine, square or triangle.

4. Amplitude Control: Continuously variable control varies output from 10V p-p to <0.1V p-p.

5. DC Offset/Ramp Frequency Control: This control varies the Ramp Frequency when the knob is pushed in. When the knob is pulled out the DC level of the output can be set to $\geq \pm 5V$ with respect to ground simultaneously.

6. Symmetry Switch: The three position slide switch provides, either extension of the +ve or -ve going signal, or waveforms with a 1:1 symmetry.

7. Ramp Amplitude/ Symmetry Control: This control has a dual function.
   (a) It varies the output amplitude of the Ramp Generator.
   (b) When the Symmetry Switch selects either +ve or -ve slope extension it adjusts the Magnitude of the extension.

8. AM on-off Switch: This switch connects an amplitude modulator into the circuit so that the output selected by the previous controls can be varied in amplitude by a suitable control voltage.

9. AM Input Socket: When the AM switch is 'ON' a +ve voltage introduced to the socket will increase the output and a -ve voltage decrease the output.

10. FM Input socket: The output frequency of the generator can be controlled by connecting a voltage to the FM input socket. A +ve voltage will increase the frequency above that set by the Frequency Dial and a negative voltage will decrease the frequency.

11. 0-10V Output Terminal: 0.1 to 10V p-p of the selected frequency and amplitude is available at an output impedance of 600Ω.

12. 0-1V Output Terminal: 0.01 to 1.0V p-p of the selected frequency and amplitude is available at an output impedance of 600Ω.

13. TTL Output Terminal: A Square wave output from 0V to $\geq +3V$ is always available at this point.

3. CONTROLS AND THEIR FUNCTIONS (continued)

3.4 Signal Source Controls (Cont'd)

14. Ramp Output: 0 to +10V Linear Ramp is available at an output impedance of 600Ω.

3.5 Amplifier Section Controls:

15. Power Amp/Bi-Polar/+5V Power Supply Switch: Position of this switch provides the user with either a Power Amplifier or a variable +15V to -15V Supply or a fixed +5V Supply.

16. Voltage Control/Bi-Polar Power Supply: With the Bi-Polar Supply in operation rotation of this control changes the output voltage over a ± 15V range as indicated on the front panel.

17. Power Amplifier Input Terminals: These terminals accept input signals for the Power Amplifier, when not in use the blue terminal becomes open circuit.

18. Power Amp/Bi-Polar/+5V Power Supply Output Terminals: The output of either the Power Amplifier or the Power Supplies appears here.

19. Voltage/Operational Amplifier Input Terminals: An Inverting (-ve) and a Non-Inverting (+ve) input is provided for both functions of the amplifier.

20. Voltage/Operational Amplifier Output Terminal: The output of either the Voltage Amp., or the Operational Amp. is available here.

21. Voltage Amplifier Gain Control: Varies the gain from 1 (0db) to 100 (40db). When turned maximum anti-clockwise, the feedback networks are removed converting the amplifier to an Operational Amplifier.

3.6 Power Supply Section Controls:

22. -1 ► -15V Voltage Control: Rotation of this control provides a continuously variable output voltage from approx. - 1 to > -15V from the:-

23. -1 ► -15V Output Terminal: The required load is connected between this terminal and the 0V terminal which is the common return to the:-

24. +1 ► +15V Output Terminal.

25. +1 ► +15V Voltage Control: Provides a continuously variable output voltage from approx. +1 to >+15V.

3.6 Power Supply Section Controls: (Cont'd)

26. 0V to Earth, Link - Is provided so that the common return of the two supplies can be grounded. However, either output terminal can be grounded giving up to + or - 30V.

27. 6.3V-0-6.3V AC Output Terminals: Are the outlets for a centre-topped winding on the power transformer. The winding is insulated from all other terminals and may be taken to ±200V with respect to ground.

28. 0►+200V Voltage Control: gives continuously variable adjustment of the output voltage from 0V to >+200V.

29. 0►+200V Output Terminals: The negative terminal is grounded and the positive terminal supplies 0+200V output.

30. Power ON/OFF Switch: A D.P.S.T., switch connects the mains to the power transformer providing power for the entire instrument. When power is being applied to the unit the:-

31. Power Indicator: Lights up giving a visual indication that the unit is operating.

4. OPERATION:

DESCRIPTION:	PARAGRAPH	PAGE
GENERAL	1,2	4 - 2
POWER TRANSFORMER AND AC FUSE	3	4 - 2
FUNCTION GENERATOR	4	4 - 2
FUNCTION GENERATOR DC OFFSET	4	4 - 3
FUNCTION GENERATOR SYMMETRY	4	4 - 3
FUNCTION GENERATOR FREQUENCY SWEEP	4	4 - 4
FUNCTION GENERATOR A.M.	4	4 - 5
POWER AMPLIFIER	5	4 - 5
BI-POLAR POWER SUPPLY	6	4 - 6
+5V FIXED SUPPLY	7	4 - 6
VOLTAGE AMPLIFIER	8	4 - 7
OPERATIONAL AMPLIFIER	9	4 - 7
+ AND -15V VARIABLE POWER SUPPLIES	10	4 - 9
6.3V AC OUTPUT	11	4 - 10
0→200V VARIABLE POWER SUPPLY	12	4 - 11

4. OPERATION (continued)

4.1 The purpose of this section is to outline the use of each separate function of Model BWD 603B. For usage requiring interconnection between sections refer to 'APPLICATION, SECTION 5'.

4.2 Throughout this section and the following section, drawings of the front panel and its controls are used to describe settings of switches and knobs.

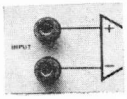
(a) Where a push button switch is shown, ⊗ that switch should be depressed. Otherwise the button should be released.

(b) The position of knobs is shown by an arrow on the front of the knob. The panel control should be aligned so that the arrow points in the approximate direction as the drawing.

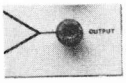
(c) Where no arrow appears on the drawing of a particular knob, the position of that control has no effect on the operation.

(d) The position of the Frequency Dial is shown by aligning the number shown on the drawing, against the vertical line at the top of the dial.

(e) Any inputs are designated thus:-



(f) Outputs are designated thus:-



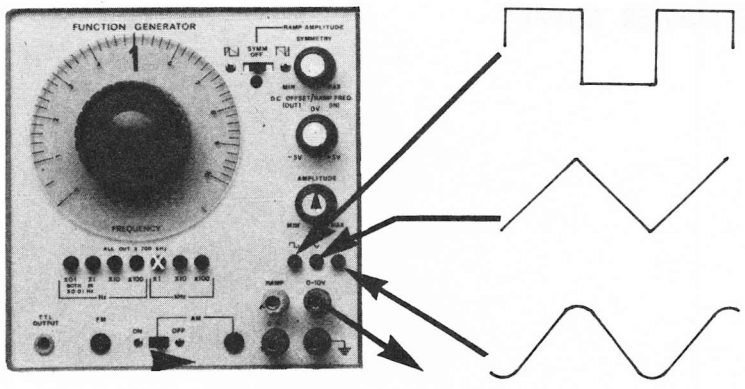
4.3 Check that the power transformer is connected correctly for the mains supply to which the unit will be connected. If the connection is incorrect refer to section 2.28.

Check the fuse rating on the rear panel of the unit and replace if necessary.

The 3 pin plug may now be inserted into the correct receptacle and power applied via the front panel Power ON/OFF switch and any external power switch.

4.4 Operation of the Function Generator:

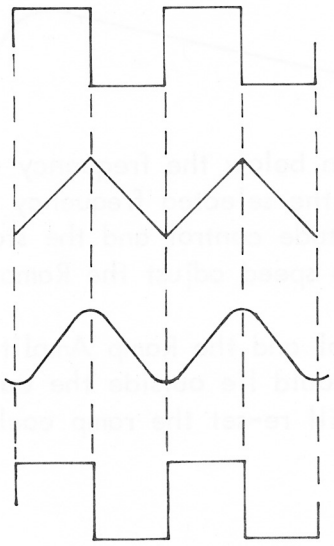
With the controls set as shown below the three waveforms drawn to the right of the panel can be produced by depressing the indicated push button.



4.4 Operation of the Function Generator (Cont'd)

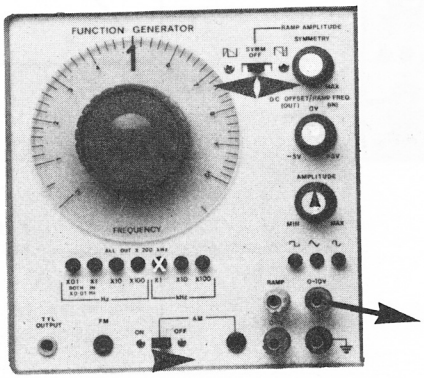
The frequency of operation will be approximately 1kHz. Variations of the Frequency Dial enables signals within the frequency range of 100Hz to 10kHz to be generated. The frequency does not change when the Function Selector is used to produce the three different waveforms.

The output amplitude can be adjusted via the Amplitude Control from 0.1V pp to 10Vpp from the main output terminal and from 0.01V pp to 10V pp from the main output terminal and from 0.01V pp to 1.0V pp from the 0-1V output terminal. A TTL compatible output is permanently available from the terminal marked TTL on the front panel. The phase relationship between the TTL output and the other waveforms is shown below:-

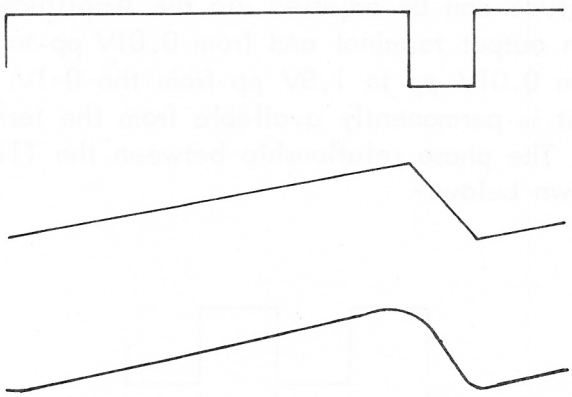


Offset voltage can be superimposed on the output waveform by pulling the Offset Control out until it clicks and then rotating the control either side of the centre point of its rotation. Pushing the knob back in renders the control in-operative.

By setting the symmetry controls as shown below the effect of variable symmetry can be seen:-

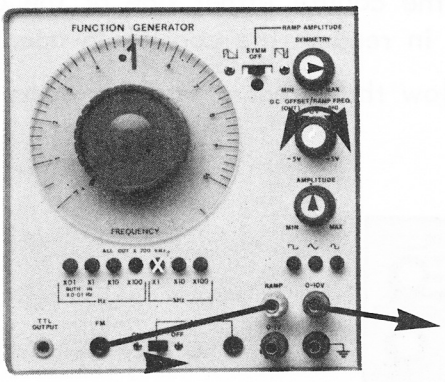


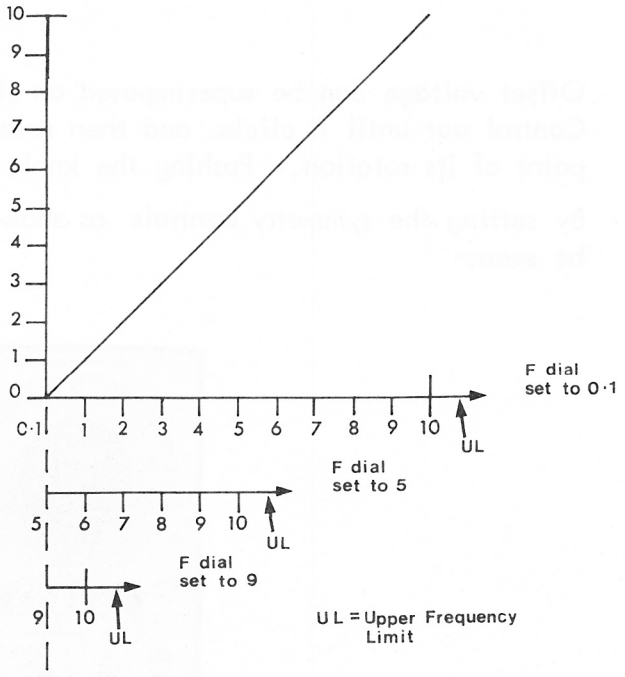
The symmetry change of the waveform is achieved by increasing the time duration between alternate half cycles. The beginning of a cycle of the square wave switching waveform coincides with the peaks of both the Sine and Triangle waveforms, hence the overall effect is to decrease frequency as the symmetry ratio changes from 1:1 to either 50:1 or 1:50. Since the symmetry control works on all three output waveforms the three waveforms appear as below:-



Setting the controls as shown below the frequency of the generator can be swept over any desired portion of the selected frequency range. The sweep width is adjusted by the Ramp Amplitude control and the starting frequency by the Frequency control. To vary the sweep speed adjust the Ramp Frequency control.

Should the Frequency Control and the Ramp Amplitude control be set such that the upper frequency limit would lie outside the calibrated range, an automatic frequency limiting circuit will re-set the ramp each time it exceeds the calibrated frequency limit.

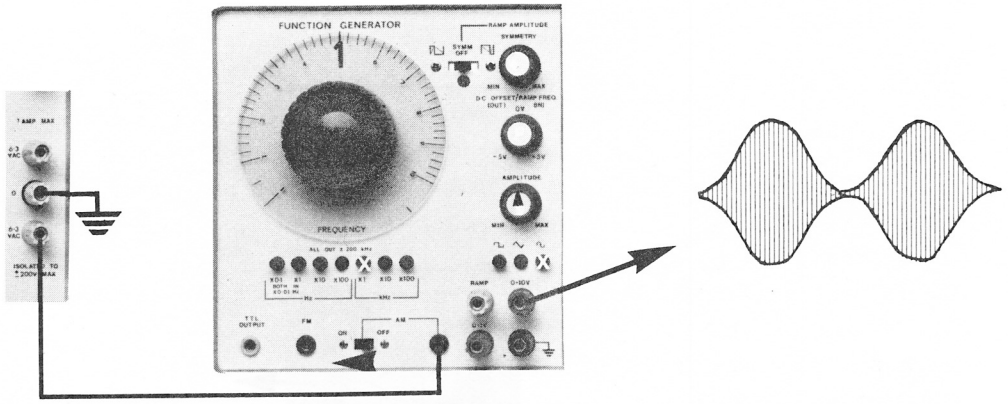




Operation of the Function Generator (continued)

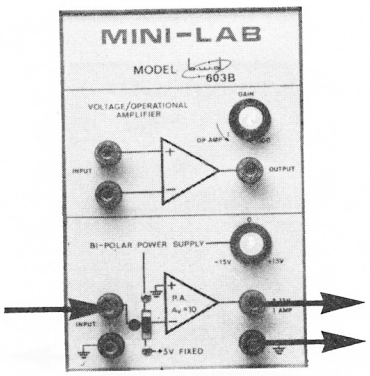
If it is required to control the frequency with an external voltage the lead from the RAMP output can be disconnected and the external voltage fed into the F.M. input socket. The voltage/frequency relationship is shown by the graph on the opposite page, but no upper limit indication is available.

To show the effect of 50Hz sinewave modulation, connect the 6.3V AC source to the A.M. input as shown to produce the waveform shown below:-



4.5 Operation of the Power Amplifier:

Set the controls as shown below:-

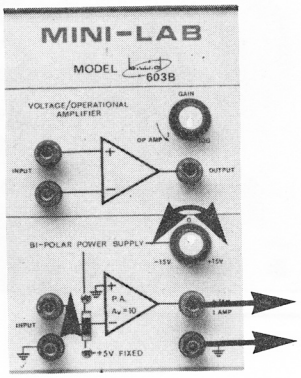


4.5 Operation of the Power Amplifier (Cont'd)

Connect the load where indicated. An input signal can be obtained either externally or from the output of the Function Generator. NOTE: that an input of ± 1.5V will give an output of ±15V which is the maximum specified output, however, if the load impedance is low, the current may exceed ±1Ampere and the automatic overload will operate producing a distorted output waveform. To produce an audible output a speaker may be connected as a load.

4.6 Operation of the Bi-Polar Power Supply:

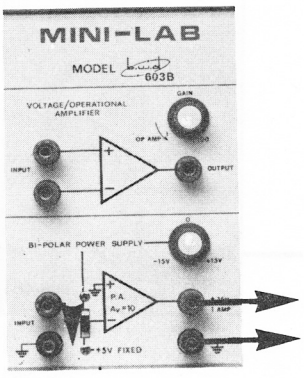
Set the controls as shown below and connect the load across the output terminals.



The required output voltage can be set using the Output Voltage Control. For accurate voltage setting an external meter or DVM should be connected across the output terminals.

4.7 Operation of the +5V Fixed Power Supply:

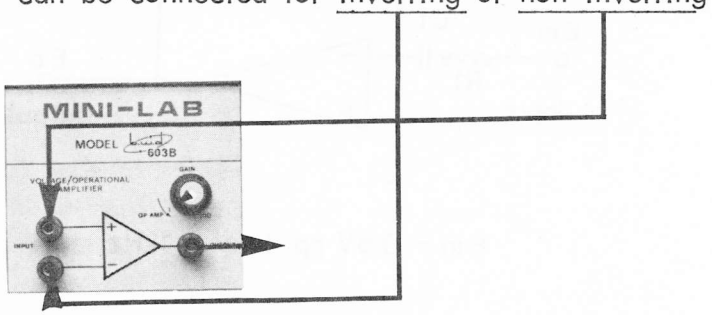
Set the controls as shown below and connect the load across the output terminals. The output voltage will lie between 4.9 and 5.1V from a 0 to 1 amp load.



4. OPERATION (continued)

4.8 Operation of the Voltage Amplifier:

Set the gain control to x1 but ensure the control is not switched to 'Operational Amplifier'. The input signal can be connected for inverting or non-inverting output as shown below:



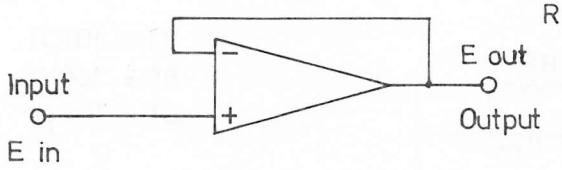
By varying the Gain Control the gain can be adjusted from x1 to x100. NOTE: that the input signal will need to be very small for a gain of 100 i.e. if the input voltage is ±100mV the output voltage will be ±10V. The x0.1 output of the Function Generator will give an output from 10mV to 1V pp, which is suitable for demonstrating the amplifier. NOTE: When using the amplifier ground the unused input signal.

4.9 Operation of the Operational Amplifier:

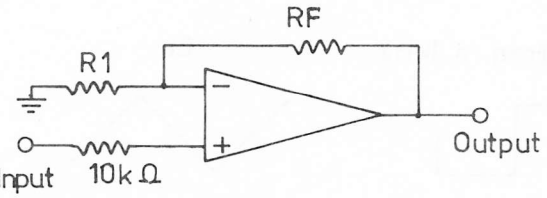
Set the Voltage Amplifier Gain control to maximum anti-clockwise ensuring that the rotary switch is switched to 'OP AMP'. The resulting amplifier has open circuit inputs and no negative feedback, giving it a gain of approximately 100db (100,000). For most practical purposes this gain can be considered to be infinite, making the effective gain of any practical circuits dependent on external components. The following circuits can be constructed using the Operational Amplifier and a few external components.

(a) Voltage Follower

R(in) $> 100M\Omega$
R(out) $< 50\Omega$

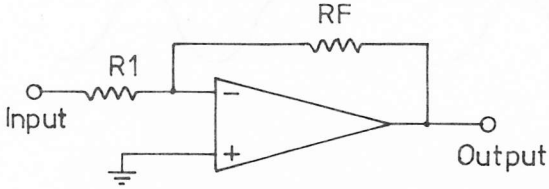


(b) Non-Inverting Amplifier



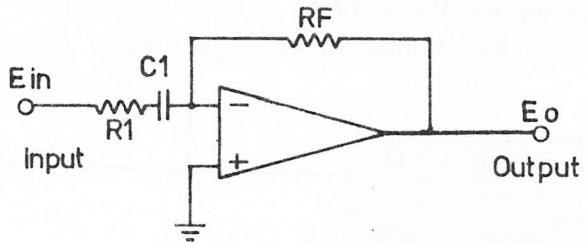
$$Av. = 1 + \frac{RF}{R1}$$

(c) Inverting Amplifier



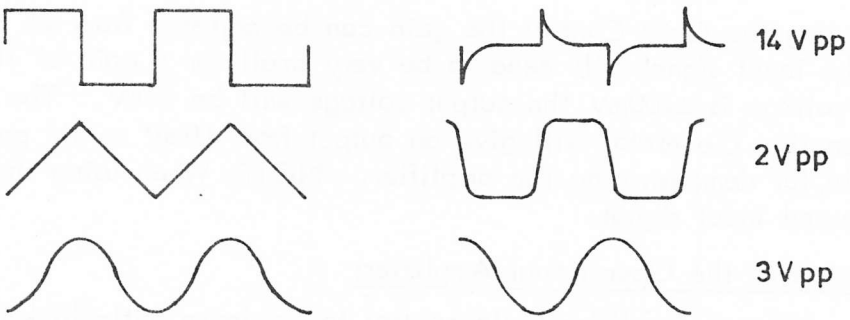
$$Av. = \frac{RF}{R1}$$

4.9 Operation of the Operational Amplifier (Cont'd)



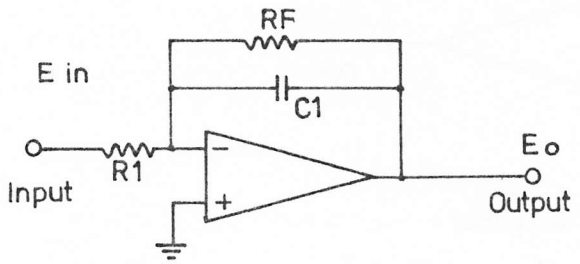
R1 = 470Ω
RF = 10KΩ
C1 = 0·1μF

Ein = 0·5V pp freq. = 1kHz



NOTE: To preserve the correct shape of the input waveform the Function Generator output should be amplified by the Power Amplifier which has less than 0.2Ω output impedance and will not be affected by the loading of the input.

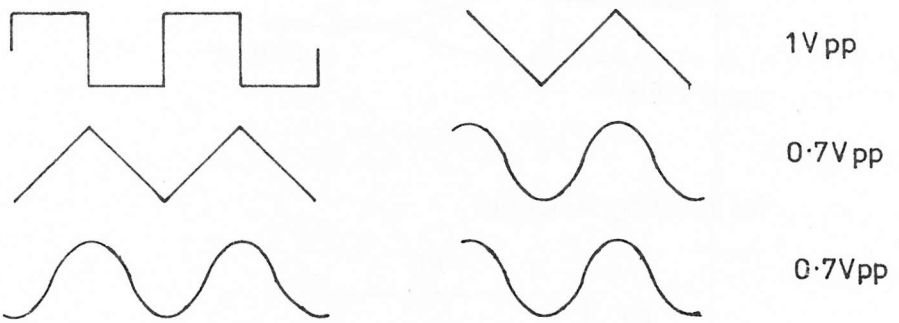
Integrator.



R1 = 10KΩ
RF = 100KΩ
C1 = 0·1μF

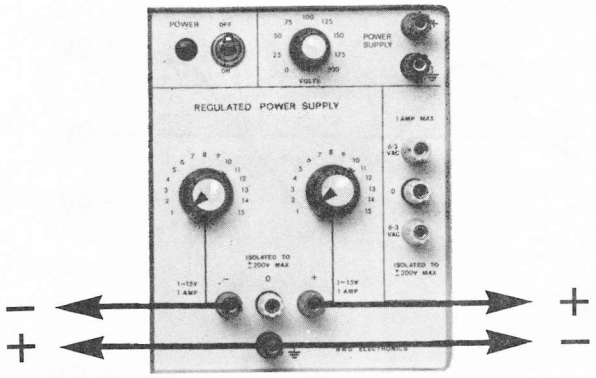
$$E_o = -\frac{1}{R1 \cdot C1}\int E_{in}\,dt$$

Ein = 5Vpp freq. = 1kHz



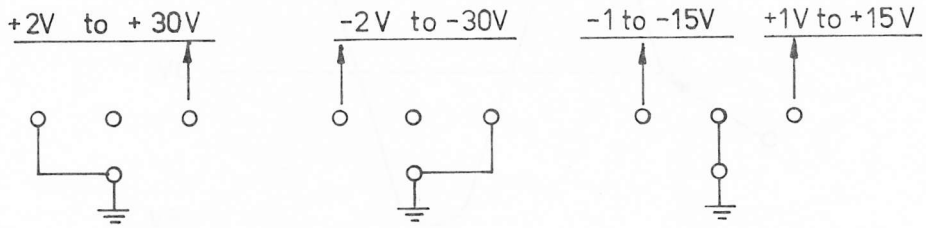
4.10 Operation of the + and - 15V Variable, Regulated Power Supplies:

The range of the independently variable supplies is 1 to 15 volts. The controls as set below will produce + and - 1V from the terminals indicated:-



Adjustment of either the positive or negative control will produce, at the corresponding terminal, the voltage indicated by the dial. Both supplies have a common terminal which is isolated from the instrument ground when the earth link is removed.

The supplies can now be connected to produce the following sources:-

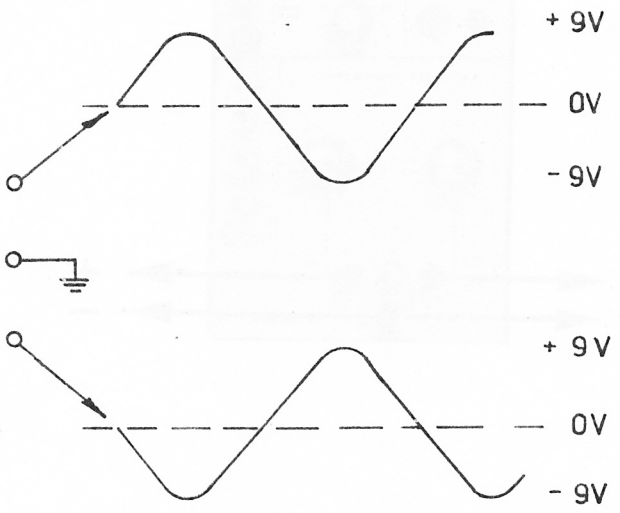


The grounded terminal in the three diagrams above can be taken to + or -200V with respect to ground increasing the range of other supplies or just providing a regulated source elevated from the instrument ground.

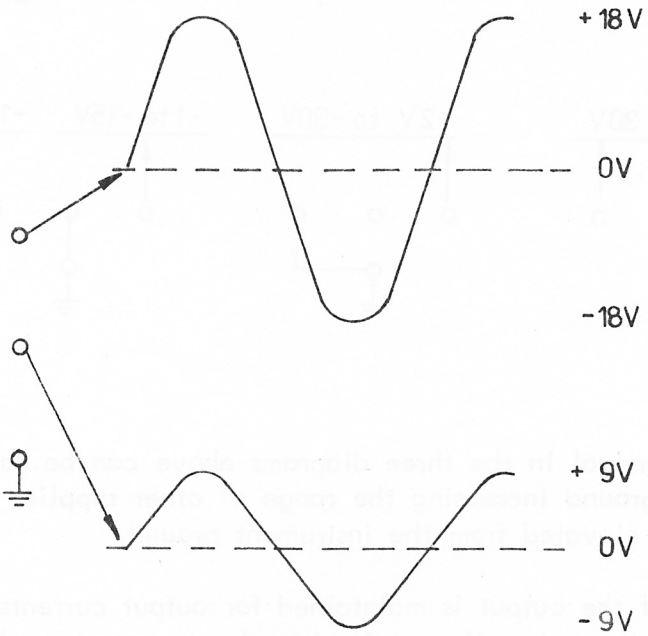
The regulation of the output is maintained for output currents up to 1 ampere. Above 1 ampere the automatic overload begins to operate reducing the output voltage as the current increases.

4.11 6.3V - 0 - 6.3V AC Output:

The three terminals provide a centre tapped 12.6V output. Using the C.T. as a common point the phase and approximate amplitude of the waveforms available is shown below:-



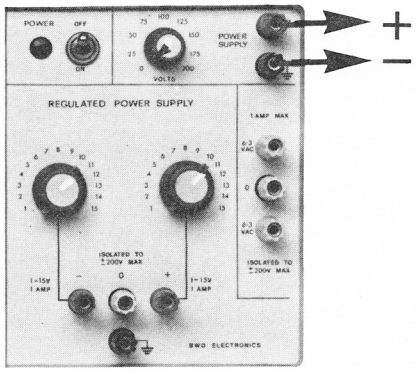
Grounding either end of the winding produces the following waveforms:-



Both ends of the winding are fused so that if zero output is produced at either or both outer terminals check the fuses on the rear panel.

4.12 Operation of the 0 to 200V Power Supply:

The negative terminal of this supply is internally connected to ground. With the Voltage Control adjusted as shown below and the load connected as shown the output voltage will be zero.



Rotating the Voltage Control clockwise will increase the output voltage to the amount shown on the panel. The output voltage will be maintained for an output current of up to 30mA, any output currents higher than 30mA will cause the supply to go into an automatic overload condition where the output voltage will decrease with increasing current.

5. APPLICATIONS:

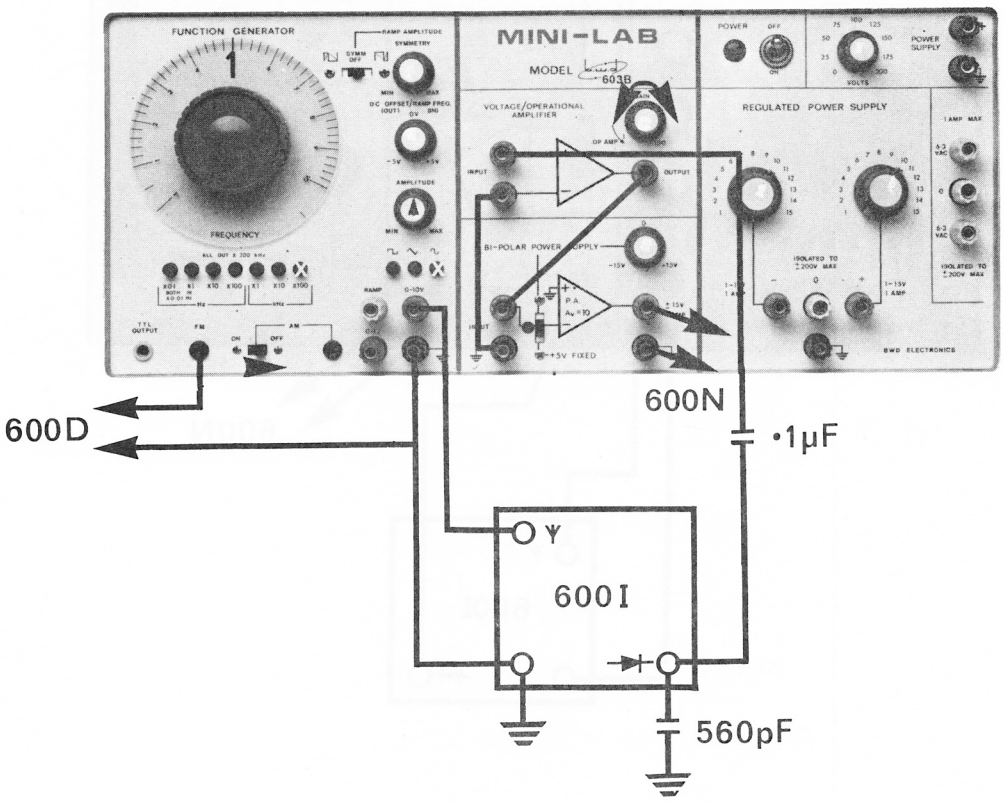
5.1 FREQUENCY MODULATION AND DE-MODULATION:

The aim of this experiment is to demonstrate the production of a Frequency Modulated carrier and to show a means of de-modulating the signal to reproduce the original modulating signal.

Equipment Required:-

(a)	1x Model BWD 603B Mini-Lab
(b)	1 x Model BWD 6001 Tuned Circuit
(c)	1x Model BWD 600D Microphone
(d)	1x Model BWD 600N Loudspeaker
(e)	Various leads
(f)	1x 0.1μF Capacitor
(g)	1x 560pF Capacitor

The equipment is connected up as shown below:-



The transmitter section produces the F.M. signal and feeds it into the tuned circuit. By adjusting the tuned circuit so that the centre frequency of the F.M. signal occurs on the slope of the response, a change in frequency will result in a change of level across the tuned circuit. The resultant Amplitude Modulated signal is rectified by the detector diode (the R.F. is removed by C) and amplified by the two amplifiers where it can be heard in the loudspeaker or seen by an oscilloscope.

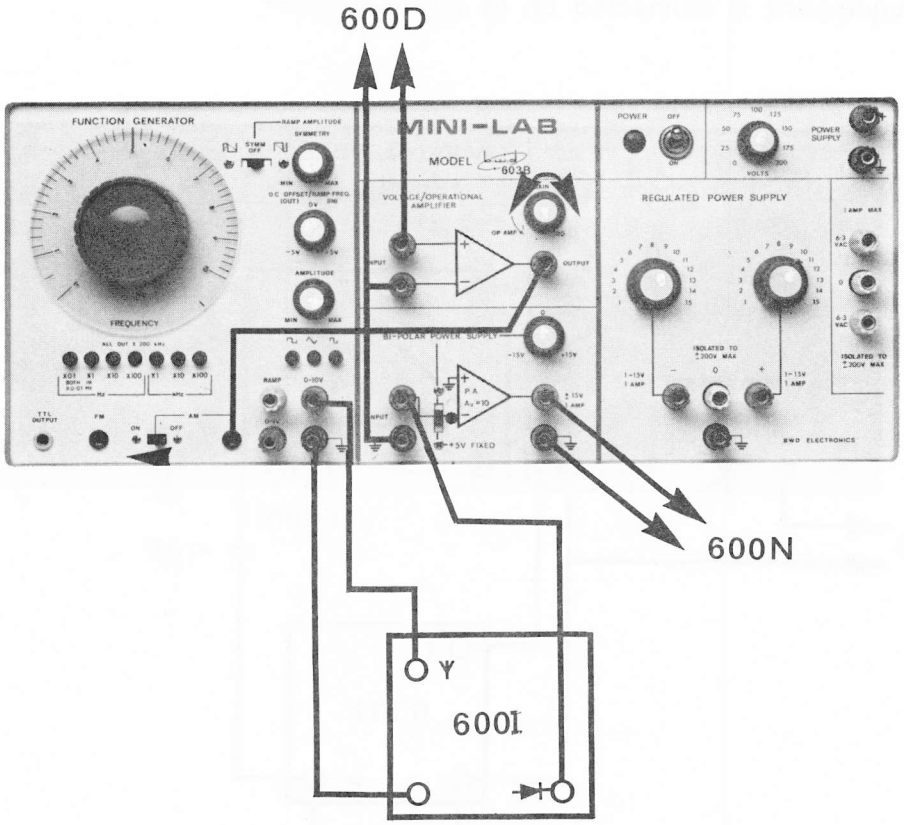
5.2 AMPLITUDE MODULATION AND DE-MODULATION:

The aim of this experiment is to demonstrate the production of an Amplitude Modulated carrier and to show a means of de-modulating to produce the original modulating signal.

Equipment Required:-

(a) 1x Model BWD 603B Mini-Lab
(b) 1x Model BWD 6001 Tuned Circuit
(c) 1x Model BWD 600D Microphone
(d) 1x Model 600N Loudspeaker
(e) Various leads
(f) 1x 0.1μF Capacitor

The equipment is connected up as shown below:-



The output from the microphone is amplified by the Voltage Amp. and taken to the A.M. input where its amplitude modulates the function generator output. This A.M. Signal is then tuned by the tuned circuit detected by the diode and amplified to produce an audible signal.

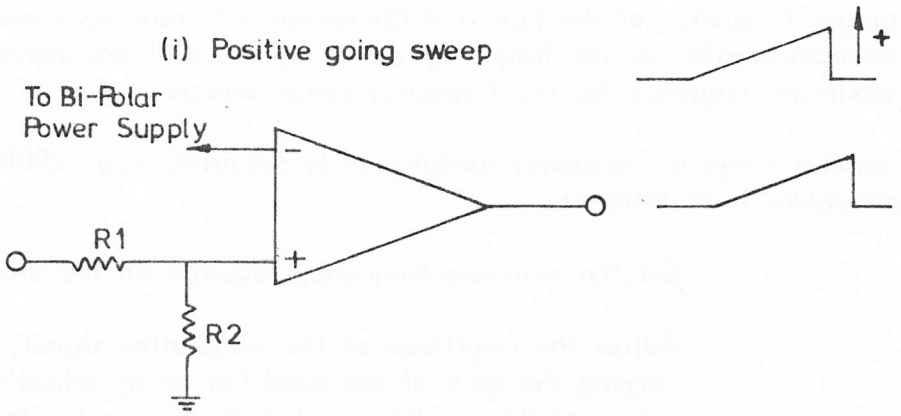
5.3 METHODS OF OBTAINING FREQUENCY SWEEP IN CONJUNCTION WITH AN OSCILLOSCOPE TO VIEW THE RESPONSE OF VARIOUS CIRCUITS:

(a) Linear Frequency Sweep:

The oscilloscope display shows a linear frequency versus horizontal deflection display. This can be achieved in the following manner:-

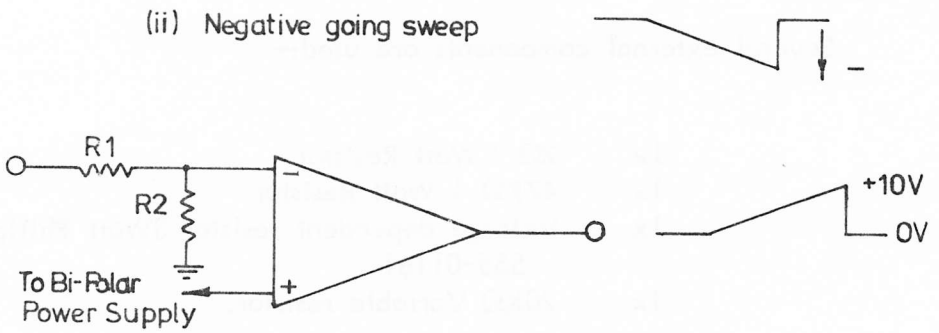
First determine the amplitude and D.C. level of the sweep output of the oscilloscope. Using the Voltage amplifier and an attenuator (if necessary) change the sweep waveform so that it starts at zero volts and increases positively to approximately +10 volts.

(i) Positive going sweep



The values of R1 and R2 are set to give less than 10V pp out of the Voltage Amplifier set to unity gain. Variation of the Bi-Polar Power Supply adjusts the D.C. level of the output and is used to set the start of the sweep at zero volts. If the sweep output from the oscilloscope starts at zero volts the negative terminal of the amplifier may be grounded. The gain control will adjust the peak to peak value of the output signal.

(ii) Negative going sweep



5.3 METHODS OF OBTAINING FREQUENCY SWEEP IN CONJUNCTION WITH AN OSCILLOSCOPE TO VIEW THE RESPONSE OF VARIOUS CIRCUITS (Cont'd)

The values of R1 and R2 are set to give less than 10V pp out of the Voltage Amplifier set to unit gain. Variation of the Bi-Polar Power Supply adjusts the DC level of the output and is used to set the start of the sweep at zero volts. If the sweep output from the oscilloscope starts at zero volts the +ve terminal of the amplifier may be grounded. The gain control will adjust the peak to peak value of the output signal.

Having produced the appropriate signal for modulating the Function Generator, the frequency dial of the generator is set to 0.1 and the output of the Voltage Amplifier is connected directly to the F.M. input socket.

The output frequency of the Function Generator will now vary over approximately two decades starting at the frequency shown by the dial and increasing linearly to the maximum frequency for the frequency range selected.

If a smaller range of frequency modulation is required, e.g. 200Hz to 300Hz the procedure is as follows:-

(1) Set the minimum frequency required on the dial (200Hz).

(2) Adjust the amplitude of the modulating signal, either by varying the gain of the amplifier or by adjusting the values of R1 and R2, so that the pp amplitude, in volts, is equal to the number of major scale divisions over which the frequency is to change. (From 200 to 300Hz is one major division). Then check that the start of the sweep is at zero volts and re-adjust if necessary.

(b) Logarithmic Frequency Sweep:

Whereas the linear frequency sweep covers only two decades, changing the shape of the sweep voltage and allowing the start to be below zero volts enables a sweep of up to four decades to be achieved in a manner which is usable. Both the Power Amplifier and the Voltage Amplifier are used. One to amplify the oscilloscope sweep signal and the other to provide a non-linear input/output characteristic.

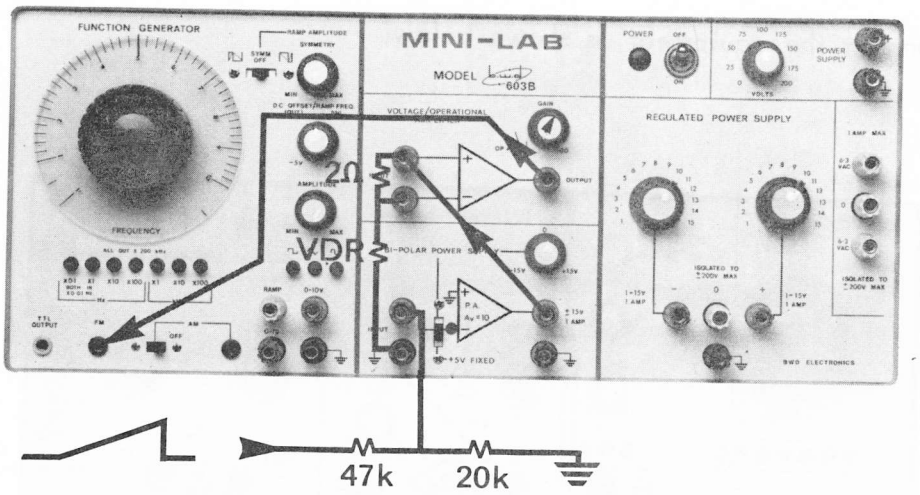
Several external components are used:-

1x 2Ω 1 Watt Resistor
1x 47KΩ $\frac{1}{2}$ Watt Resistor
1x Voltage dependent resistor 3Watt Philips No. 2322-555-01161
1x 20KΩ Variable resistor.

5.3 METHODS OF OBTAINING FREQUENCY SWEEP IN CONJUNCTION WITH AN OSCILLOSCOPE TO VIEW THE RESPONSE OF VARIOUS CIRCUITS: (Cont'd)

(b) Logarithmic Frequency Sweep (continued)

The components are connected to the unit as shown below:-



The gain of the Voltage Amplifier is varied to either increase or decrease the starting slope of the output waveform. When the desired shape is achieved the 20KΩ variable resistor should be adjusted to give the required amplitude of modulating signal.

If the oscilloscope sweep output does not start at zero volts it may be necessary to ladd a compensating voltage into the Power Amplifier input to correct the D.C. level.

Due to the non-linear nature of the modulating signal it is very difficult to obtain any form of calibration. Hence the logarithmic sweep would normally only be used for visual inspection prior to a more accurate analysis.

5.4 USE OF AMPLIFIERS IN A SIMPLE RADIO RECEIVER:

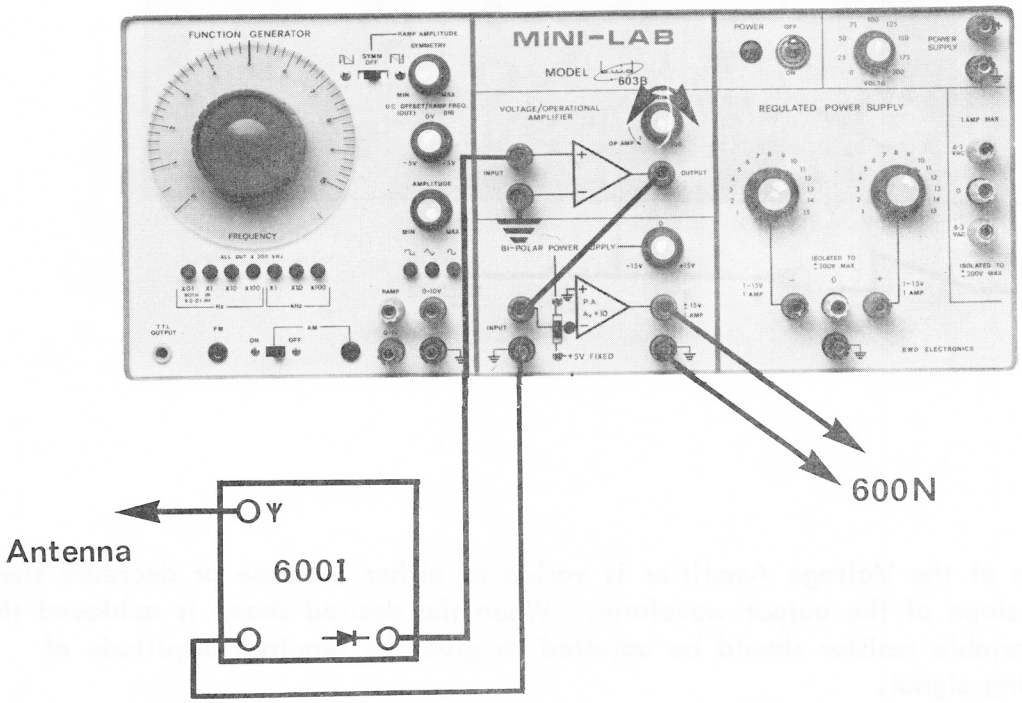
This experiment shows how the two amplifiers of Model BWD 603B can be connected to form a high gain power amplifier capable of amplifying the small signals picked up and de-modulated by a simple tuned circuit and diode circuit.

5.4 USE OF AMPLIFIERS IN A SIMPLE RADIO RECEIVER (Cont'd)

Equipment required:-

(a) 1x Model BWD 603B Mini-Lab.
(b) 1x Model BWD 600I Tuned Circuit.
(c) 1x Model BWD 600N Loudspeaker.
(d) Various leads.

Connect the equipment as shown below:



by adjusting the variable capacitor on the tuned circuit different broadcast radio stations can be heard.

5.5 USE OF AMPLIFIERS IN A SIMPLE PUBLIC ADDRESS SYSTEM:

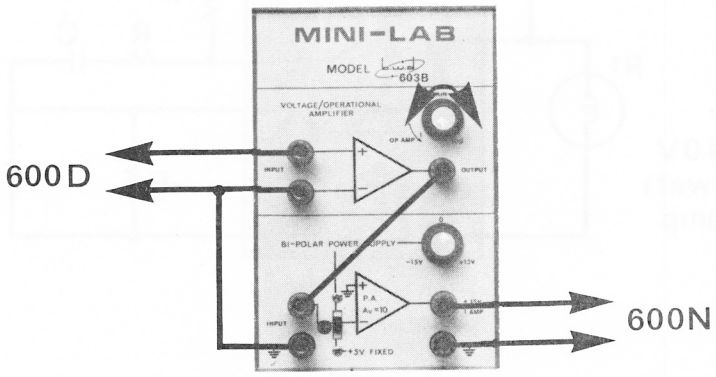
Using the same amplifier configuration as in Section 5.4, but connecting a microphone into the input of the Voltage Amplifier shows the general method of producing a Public Address System.

Equipment required:

(a) 1x Model BWD 603B Mini-Lab.
(b) 1x Model BWD 600D Microphone.
(c) 1x Model BWD 600N Loudspeaker.
(d) Various leads.

5.5 USE OF AMPLIFIERS IN A SIMPLE PUBLIC ADDRESS SYSTEM (Cont'd)

Connect the equipment as shown below:-



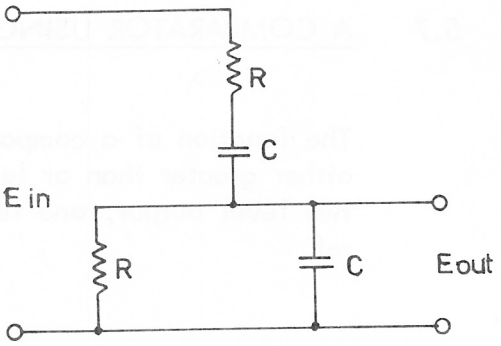
The Voltage Amplifier gain control can be used as a 'Volume Control'.

5.6 WIEN BRIDGE OSCILLATOR USING THE OPERATIONAL AMPLIFIER:

Positive feedback applied to an operational amplifier will generally cause the amplifier to oscillate. If the feedback network is arranged in such a way as to apply positive feedback at one frequency only the amplifier will oscillate at that frequency.

The frequency where the phase shift is 0^{o} is given by:-

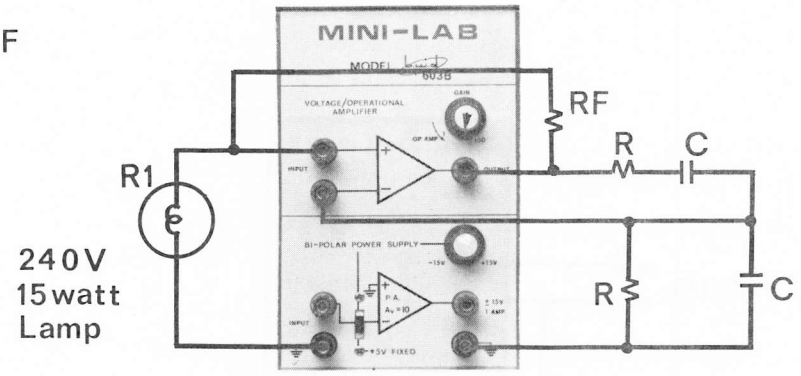
$$f = \frac{1}{2\pi RC}$$



5.6 WIEN BRIDGE OSCILLATOR USING THE OPERATIONAL AMPLIFIER (Cont'd)

The Wien Bridge network is applied to the operational amplifier in the following way:-

R = 10K
RF = 1K
C = 0·1μF



The 240V 15 Watt Lamp and RF function as an automatic level control, RF providing negative feedback and the resistance of the lamp - R1 - controlling the amount of negative feedback.

The gain of the amplifier is given by:-

$$(AV) = 1 + \frac{RF}{R1}$$

As the output of the oscillator rises the voltage across the lamp rises causing its resistance to increase. From the equation above it can be seen that as R1 increases (AV) decreases. Since the gain of the amplifier decreases, the output will decrease until the amplifier gain is just sufficient to maintain oscillations.

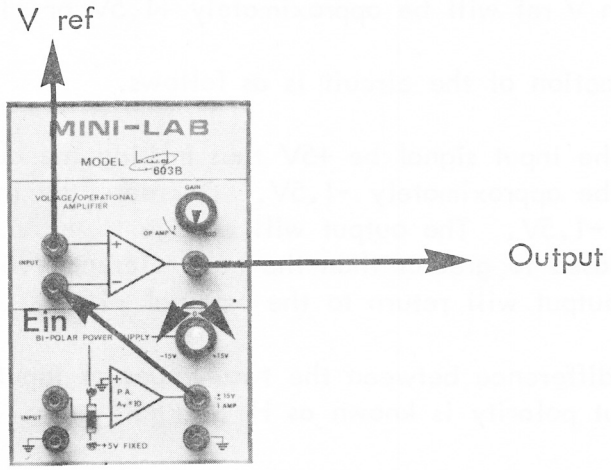
The output amplitude will be approximately 8V pp at a frequency of 160Hz.

5.7 A COMPARATOR USING THE OPERATIONAL AMPLIFIER:

The function of a comparator is to determine whether an input voltage is either greater than or less than a fixed reference voltage and provide a two level output, one level for E in < E ref the other level for in > ref.

5.7 A COMPARATOR USING THE OPERATIONAL AMPLIFIER:

Connect the operational amplifier as shown below:-



Note: V ref can be obtained from the Function Generator by turning the Amplitude control to zero and using the D.C. offset to provide a ± 5V D.C. output at the 0-10V terminal.

Set the 1 → +15V Power Supply to +5V.

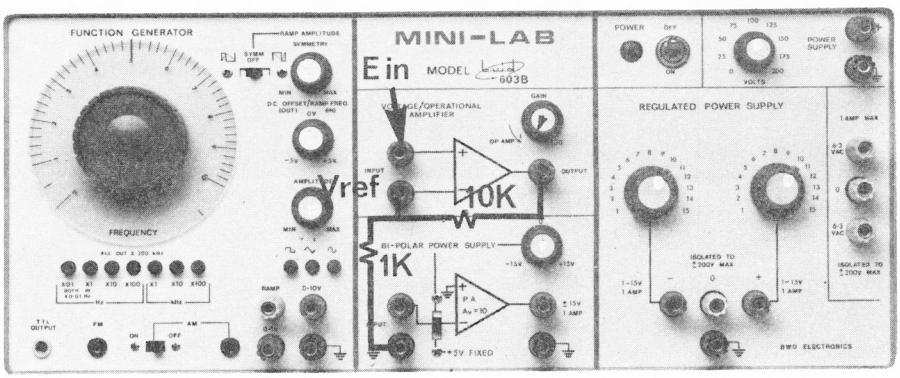
Vary the output of the Bi-Polar Power Supply and simultaneously monitor the output of the Operational Amplifier. It can be seen that if the value of Ein is less than V ref the output will be negative and if Ein is greater than V ref the output will be positive. The value of V ref can lie anywhere between ±10V.

Ein and V ref can be reversed resulting in polarity reversal of Eo.

.8 A SCHMITT TRIGGER USING THE OPERATIONAL AMPLIFIER:

The operation of a Schmitt Trigger is similar to that of a comparator except that V ref is derived from the value of Eo.

Connect the Operational Amplifier as shown below:-



5.8 A SCHMITT TRIGGER USING THE OPERATIONAL AMPLIFIER (Cont'd)

The value of the reference voltage is determined by the saturation voltage Eo and the voltage divider connected to the positive input. For the values shown V ref will be approximately +1.5V or -1.5V.

The action of the circuit is as follows.

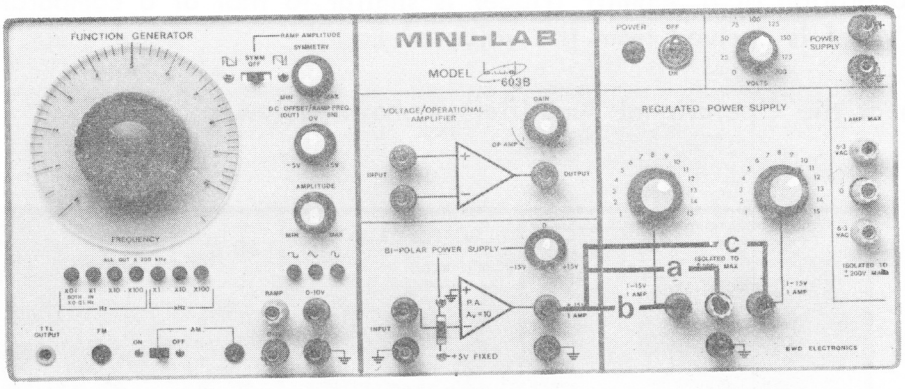
Let the input signal be +5V thus making the output saturate at -15V. Vref will now be approximately -1.5V. Decrease the input to a value more negative than -1.5V. The output will change to +15V. The input signal must now be increased to greater than the new reference voltage, which is +1.5V, before the output will return to the original -15V.

The difference between the two values of input signal required to change the output polarity is known as HYSTERESIS.

Variation of the voltage divider valued will result in different values of HYSTERESIS.

5.9 ADDING THE POWER SUPPLIES IN SERIES TO PRODUCE HIGHER VOLTAGE RANGES:

Since the 1 -15 and 1 +15V supplies are not connected to the instrument ground (FLOATING) they may be added in series with the output of the Bi-Polar Power Supply thereby increasing the total output voltage. The three methods of connecting the Bi-Polar Power Supply output are shown below and the voltage ranges are detailed after the diagram.



5.9 ADDING THE POWER SUPPLIES IN SERIES TO PRODUCE HIGHER VOLTAGE RANGES (Cont'd)

(a) Bi-Polar Power Supply to the common terminal.
The total voltage range available at the +1→+15V terminal is -14V to +30V.
The total voltage range available at the -1→-15V terminal is +14V to -30V.

(b) Bi-Polar Power Supply to the +1→+15V terminal.
The total voltage range available at the -1→-15V terminal is +13V to -45V.
The total voltage range available at the common terminal is 0V to -30V.

(c) Bi-Polar Power Supply to the -1→-15V terminal.
The total voltage range available at the +1→+15V terminal is +13V to +45V.
The total voltage range available at the common terminal is 0V to +30V.

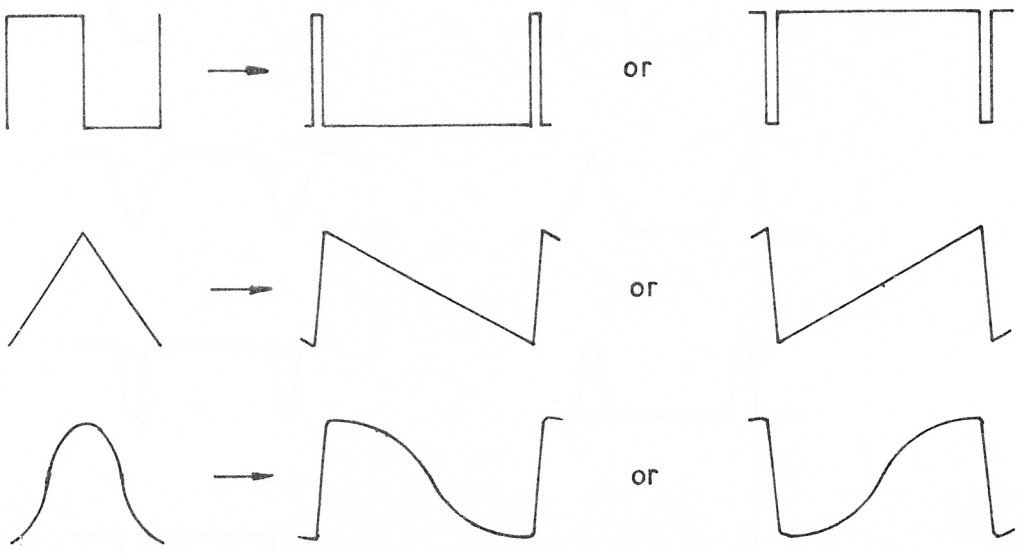
5.10 SUPERIMPOSITION OF A.C. SIGNALS ON A D.C. POWER SOURCE:

Using the connections given in Section 5 - 9 but switching the Bi-Polar Power Supply to Power Amplifier and driving the input of the Power Amplifier with the Function Generator provides a wide range of A.C. signals which can be superimposed on the D.C. power supplies.

The A.C. signals can be used to simulate ripple signals or switching pulses on power lines.

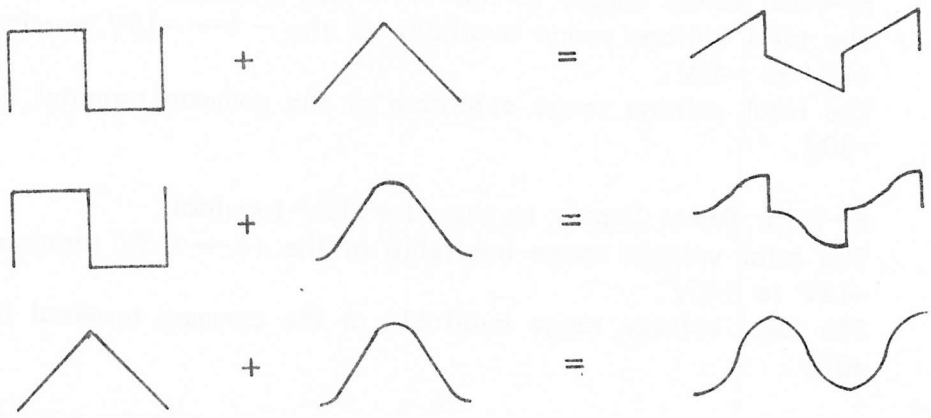
5.11 MISCELLANEOUS WAVEFORMS USING SYMMETRY CONTROL:

By using the symmetry control the Sine, Square and Triangular waveforms can be changed into the following:-



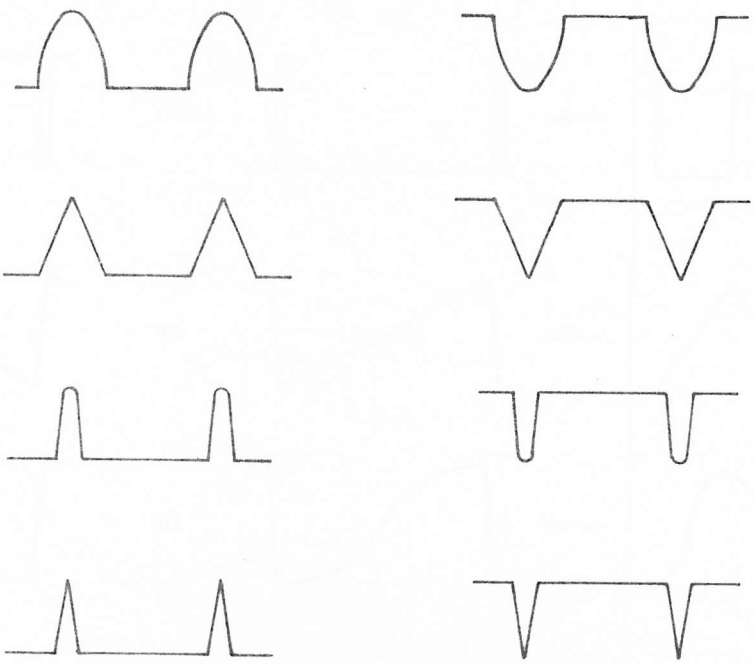
5.12 MISCELLANEOUS WAVEFORMS BY SELECTING COMBINATIONS OF ⊓, ⊓ AND ⩘ :

It is possible by pushing two or more buttons of the Function Selector Switch to get waveforms which show the addition of the waveforms selected:



5.13 MISCELLANEOUS WAVEFORMS BY CLIPPING:

When the Function Generator output is fed into the Voltage Amplifier, the following waveforms can be obtained by varying the amplitude of the input and the D.C. Offset control.

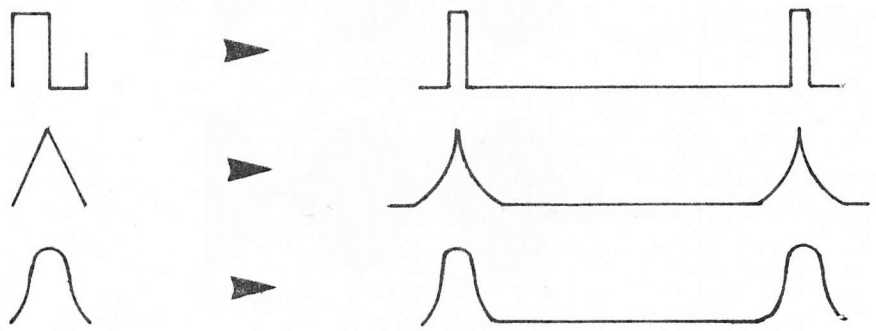


5. APPLICATIONS: (continued)

5.14 MISCELLANEOUS WAVEFORMS BY FREQUENCY MODULATING THE FUNCTION GENERATOR BY ITSELF:

(a) Connect the output (0-10V) terminal of the Function Generator to the F.M. input socket.

Set the output level to maximum clockwise and vary the DC Offset to produce the required waveform:



(b) Connect the Function Generator output (0-10V) to either the +ve or -ve input of the Voltage Amplifier.

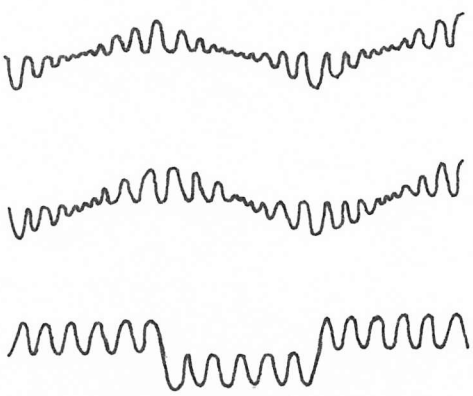
Connect the Voltage Amplifier output to the F.M. input socket. No DC Offset is required.

The gain of the Voltage Amplifier is used to vary the waveforms and inversion of the waveforms can be accomplished by reversal of the Voltage Amplifier input connections. The waveforms are as above.

5.15 MISCELLANEOUS WAVEFORMS PRODUCED BY AMPLITUDE MODULATION:

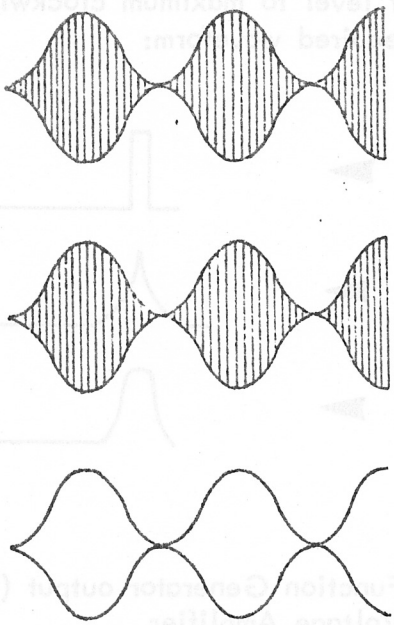
Connect the 6.3V AC terminal via a 39KΩ resistor to the A.M. input socket. Also connect the 0V A.C. terminal to any ground (⏚) terminal. The frequency of the modulating signal is then equal to the mains frequency, i.e. 50 or 60Hz.

With the A.M. switched ON and the function generator frequency set to 1Hz, the following waveforms can be displayed:-



5.15 MISCELLANEOUS WAVEFORMS PRODUCED BY AMPLITUDE MODULATION (Cont'd)

Re-set the Function Generator frequency to 1kHz.



6. CIRCUIT DESCRIPTION:

6.1 The complete circuit of Model BWD 603B is divided into 5 discrete drawings, the numbers and contents are listed below:-

Drg. No. 1358	Triangle and Square Wave Generators.
Drg. No. 1357	Sine Wave Shaper, Amplitude Modulator and Function Generator Output Amplifier.
Drg. No. 1383	Ramp Generator.
Drg. No. 1356	Power Amp/Bi-Polar Supply, Voltage/Operational Amplifier and 0-200V Power Supply.
Drg. No. 1355	+ and -15V Reg. Var. Power Supplies, + and -15V Fixed internal supplies, Power Rectifiers and Filtering.

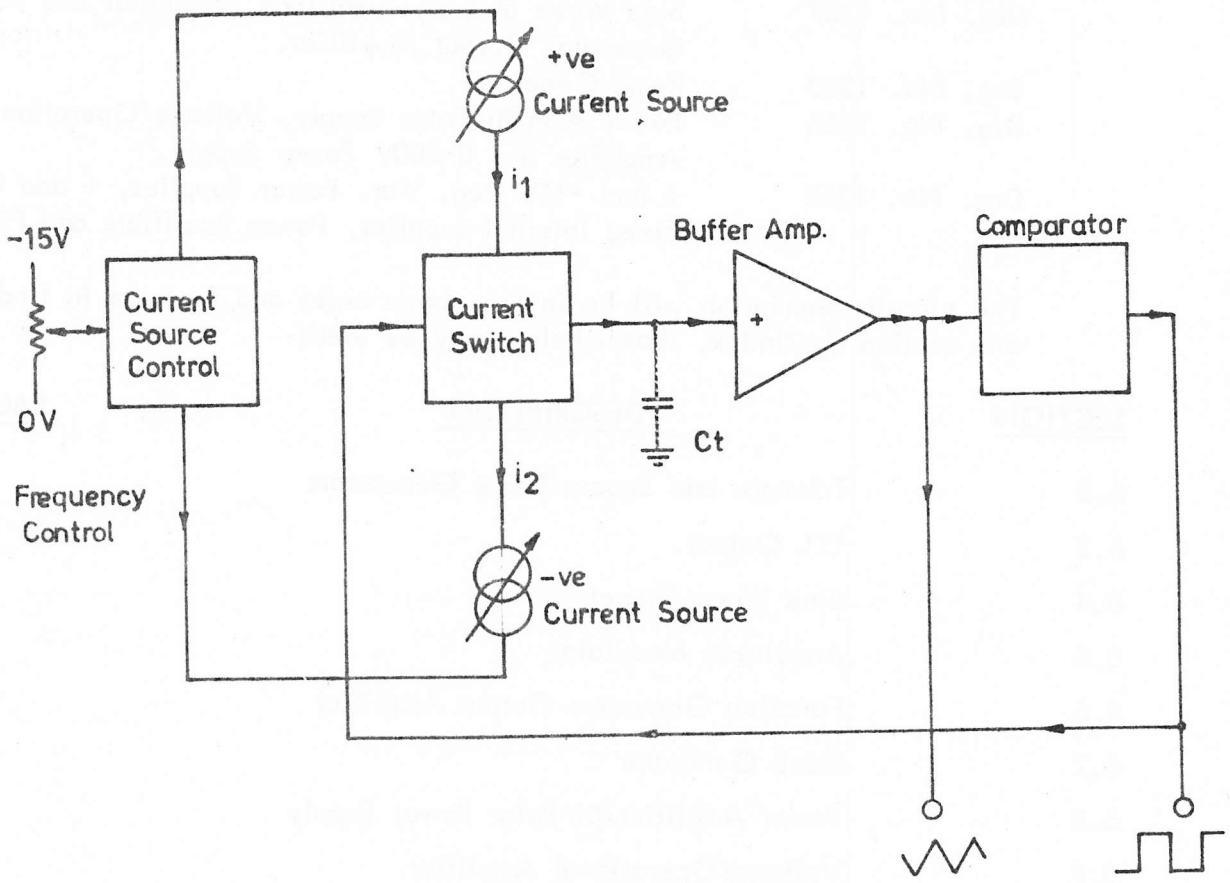
The circuit description will be in the above order and for ease in finding any one section the index, shown below, may be used:-

SECTION	DESCRIPTION	PAGE
6.2	Triangle and Square Wave Generators	
6.3	TTL Output.	
6.4	Sine Wave Shaper	
6.5	Amplitude Modulator	
6.6	Function Generator Output Amplifier	
6.7	Ramp Generator	
6.8	Power Amplifier/Bi-Polar Power Supply	
6.9	Voltage/Operational Amplifier	
6.10	Variable 0 - 200V Power Supply	
6.11	+ and -15V Regulated, Variable Power Supplies	
6.12	+ and -15V Regulated, Fixed Internal Supplies	
6.13	Power Rectifiers and filters	

6.2 TRIANGLE AND SQUARE WAVE GENERATORS (Drg. No. 1358)

Both the triangle and square waves are generated simultaneously, the square wave being used to switch the current sources used to generate the triangle and the triangle used via a comparator to produce a square wave. The block diagram on the next page shows the interconnection of the various parts.

6.2 TRIANGLE AND SQUARE WAVE GENERATORS (Drg. No. 1358) (Cont'd)



The variable voltage produced by the frequency vernier is amplified and inverted to produce two equal and opposite voltages which control the two current sources. The current switch passes either i_1 or i_2 to Ct the timing capacitor producing a linear voltage ramp which is +ve going when i_1 is applied and -ve when i_2 is applied. The signal across Ct is passed through the buffer amplifier, which has a very high input impedance, to the comparator. Hysteresis of the comparator enables the input waveform to operate between +0.6V and -0.6V with switching occurring at + and -0.6V.

Assuming the comparator is switched in such a way as to allow the current switch to pass i_1 , the voltage across Ct rises positively as does the output of the buffer amplifier. As the output of the buffer amplifier, and hence the comparator input, reaches +0.6V, the output of the comparator will change and via the current switch will remove i_1 , and substitute i_2 in its place. The voltage across Ct will now increase in a negative direction until the comparator input becomes -0.6V. The comparator output will change state and return the current switch to the initial state, passing i_1 , to Ct.

6.2 TRIANGLE AND SQUARE WAVE GENERATORS (Drg. No. 1358) (Cont'd)

Looking at Circuit Drg. No. 1358 the current source control is derived in the following way:-

RV2, the Frequency Vernier, produces at the -ve input of U1a a variable voltage. This voltage is inverted by U1a and becomes the input voltage for both U1b and U1c.

U1b voltage follower reproduces the input voltage at R7 whilst U1c acting as an inverter with unity gain reproduces an inverted replica of the input voltage at R13. Q2 and Q4 are the +ve and -ve current sources with their emitters fed by R7 and R13 respectively. Q1 and Q3 emitter followers produce fixed base voltages for Q2 and Q4 so that changes in control voltage via U1b and U1c produce a change in current through R7 and R13, and hence a change in current from the collectors of Q2 and Q4. D2, D3, D4 and D5 form the current switch steering either one or the other current to the timing capacitors C8 to C16.

The frequency range switch S3 to S9 selects the particular capacitor required, with S3B and S4B together selecting the low frequency range (x0.01Hz) capacitors C6 and C7. The Buffer Amplifier is composed of Q5 and 6, giving a high input impedance and a low output impedance. The Triangle output is taken from this point.

Integrated circuit U2 functions as the comparator with its output via D12, 13 and 14 taken to the current switch.

Hysteresis of the comparator is caused by feeding back a portion of the output signal to pin 5. The output of the comparator is clipped by D6 and D7 to produce a ±0.6V square wave which is used as the comparator reference. The comparator output is also clipped by D10 and D11 to produce the Square Wave output.

6.3 T.T.L. OUTPUT (Drg. No. 1358)

The inverted output of the Comparator is taken via R21 to Q7 base. Q7 amplifies the square wave and provides a 0V to +5V output at its collector.

6.4 SINE WAVE SHAPER: (Drg No. 1357)

U100 converts the triangle input (via R128) to a Sine Wave output. RV103 and RV106 set the distortion of the resultant sine wave and RV107 sets the DC level of the output.

6.5 AMPLITUDE MODULATOR: (Drg. No. 1357)

U101 is connected as variable gain amplifier. The carrier input is taken via R103 to pins 3 and 6. The modulating signal is taken via R107 and RV100 to pin 2. The output appears at pin 7, is DC level shifted by RV102 and then taken to amplifier switch S103B.

6.6 FUNCTION GENERATOR OUTPUT AMPLIFIER: (Drg. No. 1357)

The required input waveform is selected by S100, S101 and S102. S103A and B re-direct the signal through the amplitude modulator when required.

RV110 Output Level Control adjusts the level of input signal appearing at the base of Q100. The output appearing at the collectors of Q102 and Q103 is fed back to the base of Q101 via R122 providing negative feedback and a gain of approximately 20.

DC offset is taken from RV104 via R118 and S104 to the base of Q101.

6.7 RAMP GENERATOR:

C402 is alternately charged and discharged by:-

(a) The constant current source provided by Q401 and U401A.
and
(b) The negative going output of U401B via R404 and D401.

Assume the output of U401B is positive (approx. +10V). U401B functions as a comparator allowing C402 to charge from the constant current source to a DC level of approximately +0.6V. At this point the voltage across C402 becomes slightly greater than the voltage at the NON-INV input of U401B whose output switches to -10V and via R404 and D401 discharges C402 to zero volts in approximately 5mSec. The NON-INV input of U401B falls to zero volts so that when the voltage across C402 reaches zero U401B switches to a positive output allowing C402 to charge from the constant current source.

U401A is wired as a unity gain amplifier providing low loading of the frequency control (which also functions as a DC offset control) and a low source impedance for the input of Q401 constant current generator.

U401D is the output amplifier with RV401 providing variable gain and hence an output voltage control. U401D senses when the output frequency of the Function Generator reaches its upper limit for whatever range is selected. When this limit is reached it re-sets the Ramp to zero volts.

This circuit prevents ambiguous frequency sweep operation when the Ramp attempts to produce a higher frequency than the Function Generator will allow.

6.8 POWER AMPLIFIER/BI-POLAR POWER SUPPLY (Drg. No. 1356)

The input is taken via S200A and B and R201 to Operational Amplifier U200. The output of U200 is further amplified to produce a high power output at the junction of the collectors of Q202 and Q203. To maintain the gain of 10 negative feedback is applied via R202 to one of the inputs of U200. C201 limits the overall frequency response whilst C202 adjusts the HF response of the power stage only. Automatic overload protection is provided by R214, D202 and D203 in the positive direction, and R215, D204 and D205 in the negative direction. Input protection is achieved by R201 and D206.

6. CIRCUIT DESCRIPTION (continued)

6.8 POWER AMPLIFIER/BI-POLAR POWER SUPPLY (continued)

When the amplifier is used as a Power Amp., the input is taken through S200A to R201.

When used as a Bi-Polar Power Supply the input is taken to RV200 via R200 which provides at R201 a DC level adjustable to ±1.5V. When amplified by 10 the output produces a ± 15V swing.

When used as a +5V fixed supply, S200A open circuits the INV input and S200B connects the NON-INV input via R217 to the +15V rail, R217 and R203 form a voltage divider.

6.9 VOLTAGE/OPERATIONAL AMPLIFIER: (Drg. No. 1356)

S201A and B in the position shown, ground the +ve input via R220 and apply negative feedback to the -ve input via R223, R224, RV201 and C203. Variation of RV201 adjusts the amount of signal to R223 and hence the gain of the amplifier. In this 'Voltage Amplifier' mode the input impedance is set by R221 and R222 and the gain is adjustable from 1 to 100.

When S201A and B are open circuit the integrated circuit operational amplifier is connected directly to the input and output terminals without negative feedback. The 'Voltage Amplifier' has now been connected to form an 'Operational Amplifier' with an open loop gain of better than 100db. See Section 2, paragraph 15 for more details.

6.10 VARIABLE 0-200V POWER SUPPLY: (Drg. No. 1356)

The series pass transistors, Q206, Q207 control the output. Amplifier Q204 via divider network RV204, RV205 and R246, senses the output and corrects for changes via the bases of Q206 and Q207. As the output current reaches approximately 30mA the voltage across R243 and hence the base/emitter junction of Q205 reaches approximately 0.6V and Q205 starts to conduct taking base current away from Q206 and Q207. The current limiting commences at approximately 30mA and terminates at approximately 40 to 50mA into a short circuit load.

6.11 +VE and -VE 15V REGULATED VARIABLE POWER SUPPLIES: (Drg. No. 1355)

Both the +ve and -ve supplies use an integrated circuit 3 terminal adjustable regulator. U300 for the +ve supply and U301 for the -ve supply. Adjustment of the output voltage is provided by RV301 (+ve) or RV303 (-ve) with RV300 and R300 setting the maximum +ve voltage and RV302, R301 setting the maximum -ve voltage. Since both regulators are in the positive line the two supplies are independent being connected together only at the output terminal.

6.12 +VE AND -VE 15V REGULATED FIXED POWER SUPPLIES: (Drg. No. 1355)

U303 and U302, 3 terminal regulators set the + and -15V supply rails. RV320 adjusts the output of U303 to give +15V and RV321 adjusts the output of U302 to give -15V.

6.13 POWER RECTIFIERS AND FILTERS:

The rectifiers and filter capacitors together with the circuits they power are listed below:-

	Rectifiers	Filter
(a) Variable +1 ► +15V	D300 D301 D302 D303	C300
(b) Variable +1 ► -15V	D304 D305 D306 D307	C301
(c) Fixed + and - 15V	D312 D313 D314 D315	C310 (+ve) C311 (-ve)
(d) Variable 0 - 200V	D320 D321	C320 C321

7. ALIGNMENT:

Component changes will not normally affect the performance of the unit, subject to the replacement component being of similar size stability and performance to the original component.

7.1 TEST INSTRUMENTS REQUIRED:

TYPE	CHARACTERISTICS	USE
Multimeter	AC and DC Voltage to >250V DC Ampere to >2A.	Voltage and current measurement.
AC Millivoltmeter	Sensitivity 5mV FSD and 50mV FSD Frequency Range to >100MHz	Ripple and noise measurement.
Oscilloscope	"Y" Bandwidth DC 5MHz "Y" Sensitivity 10mV to >10V/cm AC and DC coupled	Viewing of various waveforms - peak to peak measurements.
Digital Frequency Meter	Frequency Range 10Hz to >1MHz	Frequency measurement.
Distortion Analyser	Freq. range >10Hz - 50kHz.	Sine distortion measurement.

7.2 GENERAL PROCEDURE:

The order of adjustments described in this section has been determined so that any adjustment will not affect a previous adjustment. RV320 and RV321 however, should be checked before any other adjustments are carried out, since the fixed ±15V rails are used throughout the unit and should they be outside the tolerances given, difficulty may be experienced. The following table shows the possible interactions of the various controls. Adjustment of a preset in column A will affect only the preset opposite an 'X' in column B.

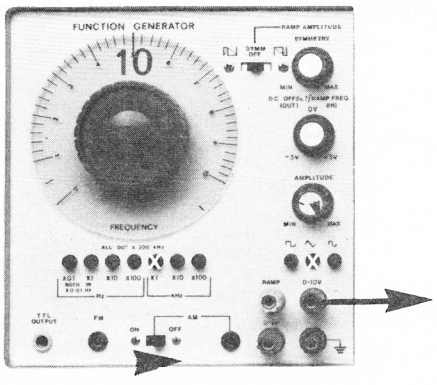
For location of presets see Section 7.24 for P.C.B. layout drawings.

Sections 7.25 onward detail the particular adjustments required for each section of the instrument together with the correct order and any precautions necessary.

	RV1	RV3	RV5	RV100	RV101	RV102	RV103	RV106	RV107	RV108	RV109	RV202	RV203	RV204	RV206	RV300	RV302	RV320	RV321	C14	C16	C23	[B]
RV1		X																					
RV3	X																						
RV5		X																					
RV100																							
RV101				X																			
RV102																							
RV103								X															
RV106							X																
RV107																							
RV108						X			X														
RV109																							
RV202																							
RV203																							
RV204																							
RV206														X									
RV300																							
RV302																							
RV320		X	X			X	X	X		X			X										
RV321	X	X	X			X		X		X			X	X									
C14																							
C16																							
C23																				X	X		
[A]																							

7.3 RV1 SET MAXIMUM FREQUENCY:

Set the Function Generator controls as shown below:-



7.3 RV1 SET MAXIMUM FREQUENCY: (Cont'd)

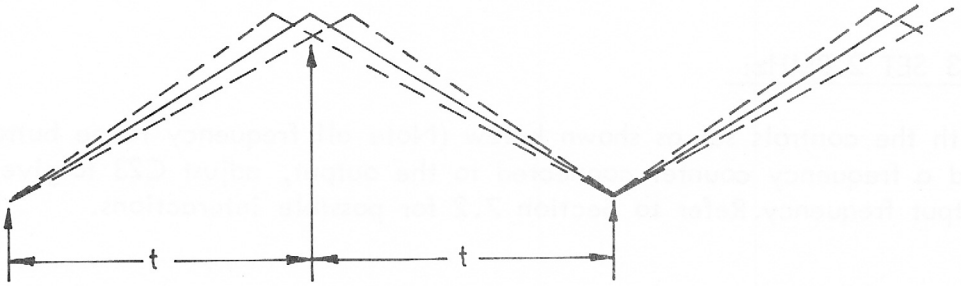
The frequency meter is connected to the output terminals and RV1 is adjusted to give 10kHz output.

7.4 RV3 SET MINIMUM FREQUENCY:

With the controls set as for RV1 adjust the frequency vernier to 1.0. RV3 is adjusted to give 1kHz output. It may now be necessary to re-set RV1 and then check RV3. Since these preset controls interact with one another it may be necessary to adjust both RV1 and RV3 several times to achieve calibration.

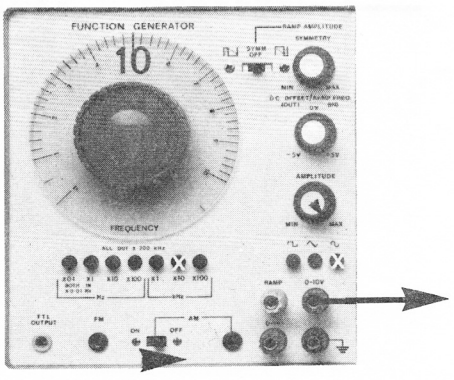
7.5 RV5 SET 1:1 SYMMETRY:

This control sets the fixed symmetry at the lower frequency end of the dial and if a large adjustment is required the setting of RV3 will require re-adjustment. Set the controls as for RV1 with the frequency vernier set to 0.1. Connect the oscilloscope to the Function Generator Output Terminals. RV5 is set to produce a triangle where positive and negative peaks are spaced equally apart.



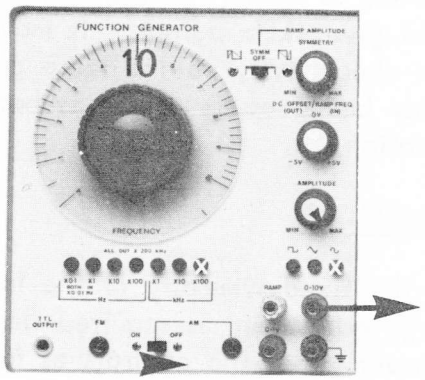
7.6 C14 SET 0.1MHz:

With the controls set as shown below and a frequency counter connected to the output, adjust C14 to give 0.100MHz output frequency.



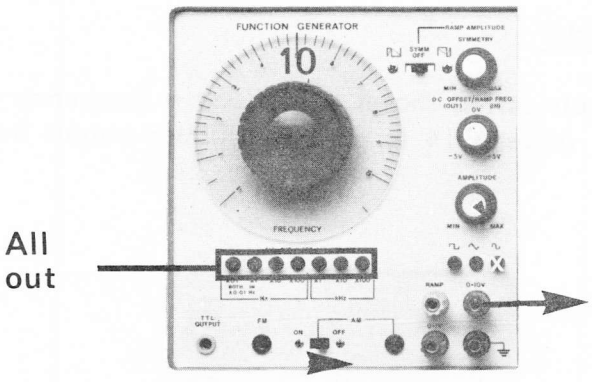
7.7 C16 SET 1.0MHz:

With the controls set as shown below and a frequency counter connected to the output, adjust C16 to give 1.00MHz output frequency.



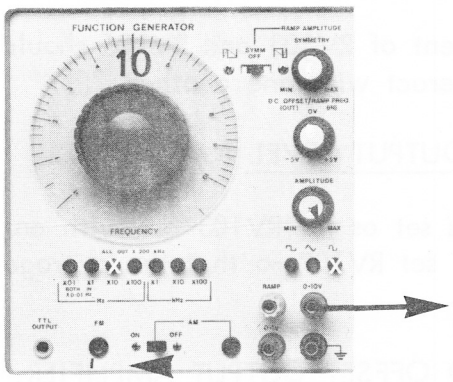
7.8 C23 SET 2.0MHz:

With the controls set as shown below (Note all frequency range buttons OUT) and a frequency counter connected to the output, adjust C23 to give 2.00MHz output frequency. Refer to Section 7.2 for possible interactions.



7.9 RV101 SET A.M. OUTPUT LEVEL:

Set the controls as shown below:-



Adjust RV101 so that the peak to peak amplitude of the triangle does not change when the A.M. ON-OFF switch is operated.

7.10 RV100 SET ZERO A.M.:

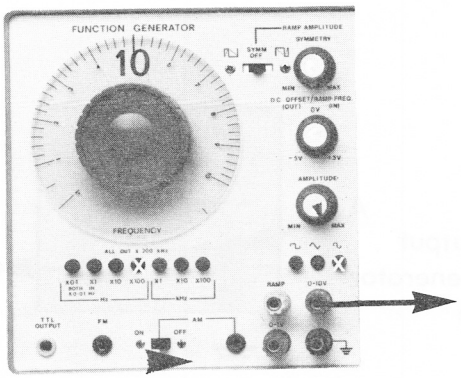
With the controls set for RV101 (Section 7.9) adjust RV100 so that the peak to peak amplitude of the triangle does not change when the A.M. input socket is grounded.

7.11 RV102 SET DC OUTPUT LEVEL (A.M.):

With the controls set for RV101 (Section 7.9) adjust RV102 so that the average DC level remains unchanged when the A.M. ON-OFF switch is operated.

7.12 RV103 SET DISTORTION BALANCE (∿):

Set the Function Generator controls as shown below and connect the Distortion Analyser to the output terminals.



RV103 is adjusted to produce a minimum distortion reading (refer to RV106).

7. ALIGNMENT (continued)

7.13 RV106 SET DISTORTION (∿):

With the controls set as for RV103 (Section 7.12) adjust RV106 to produce a minimum distortion reading.

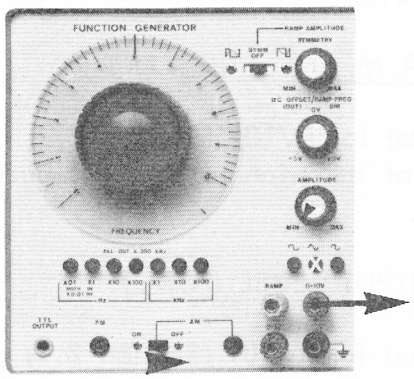
NOTE: Adjustment of RV103 and RV106 should be done at least twice as they interact with one another.

7.14 RV107 SET DC OUTPUT LEVEL (∿):

With the controls set as for RV103 but with an oscilloscope connected to the output terminals, set RV107 so that the average DC level is zero.

7.15 RV108 SET ZERO OFFSET OUTPUT AMPLIFIER:

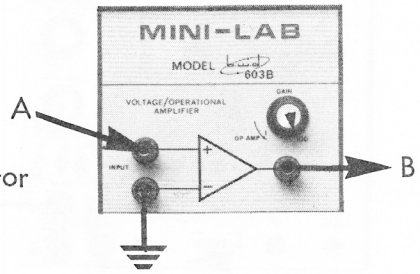
Set the controls as shown below and connect the voltmeter to the output terminals.



Adjust RV108 until the DC output level is zero.

7.16 RV202 SET x100 GAIN (OP AMP):

Set the controls as shown below and connect the input of the Amplifier as shown. Adjust the level at point A to be 0.1V p-p. Measure the signal at point B and adjust RV202 to give 10V p-p.

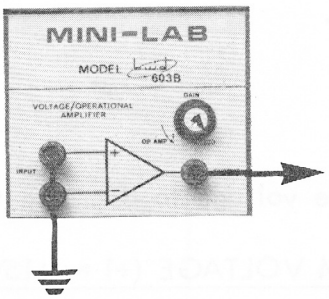


From 0-1V output of Function Generator f = 1kHz sine wave

7. ALIGNMENT (continued)

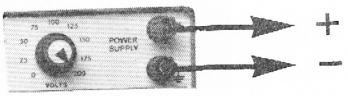
7.17 RV203 DC OFFSET (OP AMP):

Set the controls as shown below and adjust RV203 to give zero volts DC between the output terminal and ground (⏚).



7.18 RV204 SET MAXIMUM VOLTAGE (0►200V):

Set the controls as shown below and connect the voltmeter across the output terminals. RV204 is adjusted to give 200V (-0, + 10V) across the output terminals.



7.19 RV206 SET REGULATION (0►200V):

Connect the voltmeter across the output terminals and adjust the Output Voltage Control to give 150 volts output.

Connect a 5KΩ 5 Watt resistor across the output terminals and note the change in output voltage.

7.19 RV206 SET REGULATION (0 ► 200V): (Cont'd)

If it exceeds 1.5V, RV206 should be adjusted as follows:-

(a) If the voltage drops by more than 1.5V when the load is applied, turn RV206 anticlockwise.

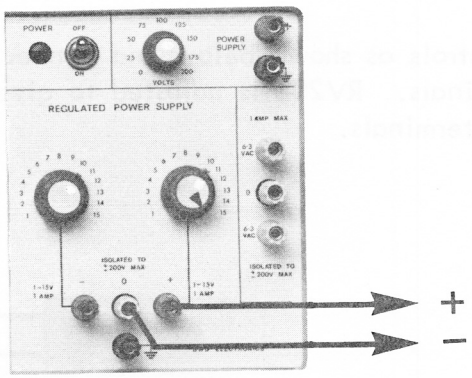
(b) If the voltage increases by more than 1.5V when the load is applied, turn RV206 clockwise.

NOTE:

It is preferable for the voltage to decrease when a load is applied.

7.20 RV300 SET MAXIMUM VOLTAGE (+1 ► +15V):

Set the controls as shown below and connect the voltmeter across the output terminals.



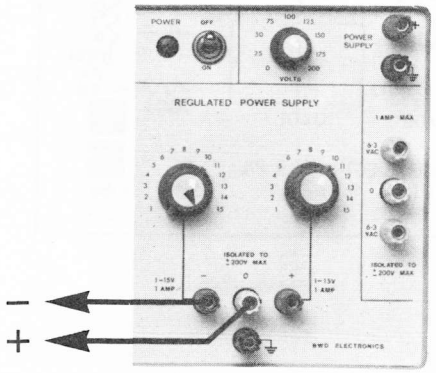
With the Output Voltage Control set to maximum clockwise, set RV300 to give approximately 16V output. Set the Output control to give 1V output and adjust the knob position on the shaft so that the pointer is opposite the "1" on the panel. Adjust the Output Voltage Control to indicate 15V and re-set RV300 to provide 15V output. As a further check, several points on the calibration can be checked and RV300 set to give the best overall result.

7.21 RV302 SET MAXIMUM VOLTAGE (-1 ► -15V):

Set the controls as shown below and connect the voltmeter across the output terminals.

7.21 RV302 SET MAXIMUM VOLTAGE (-1 ► -15V): (Cont'd)

The same procedure for setting RV300 is used for RV302 ensuring that the correct Output Voltage Control is adjusted.



7.22 RV320 SET +15V FIXED SUPPLY:

Connect the voltmeter between earth (⏚ on p.c.b.) and the fixed +15V supply. For location of the +15V supply, see Section 7.19.

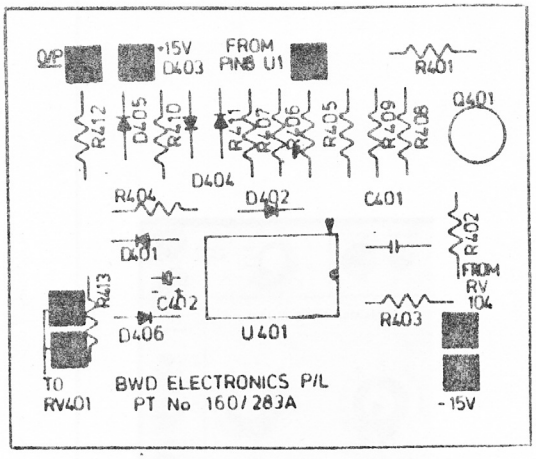
Adjust RV320 to give 15.0V indication on the voltmeter.

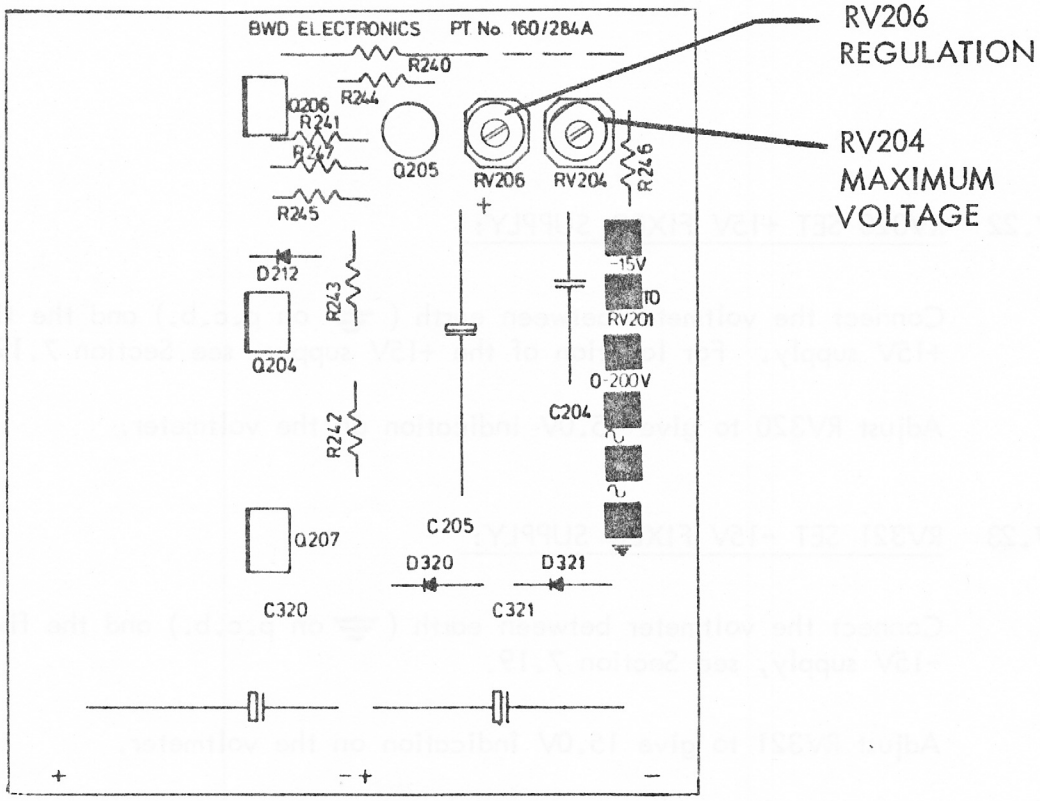
7.23 RV321 SET -15V FIXED SUPPLY:

Connect the voltmeter between earth (⏚ on p.c.b.) and the fixed -15V supply, see Section 7.19.

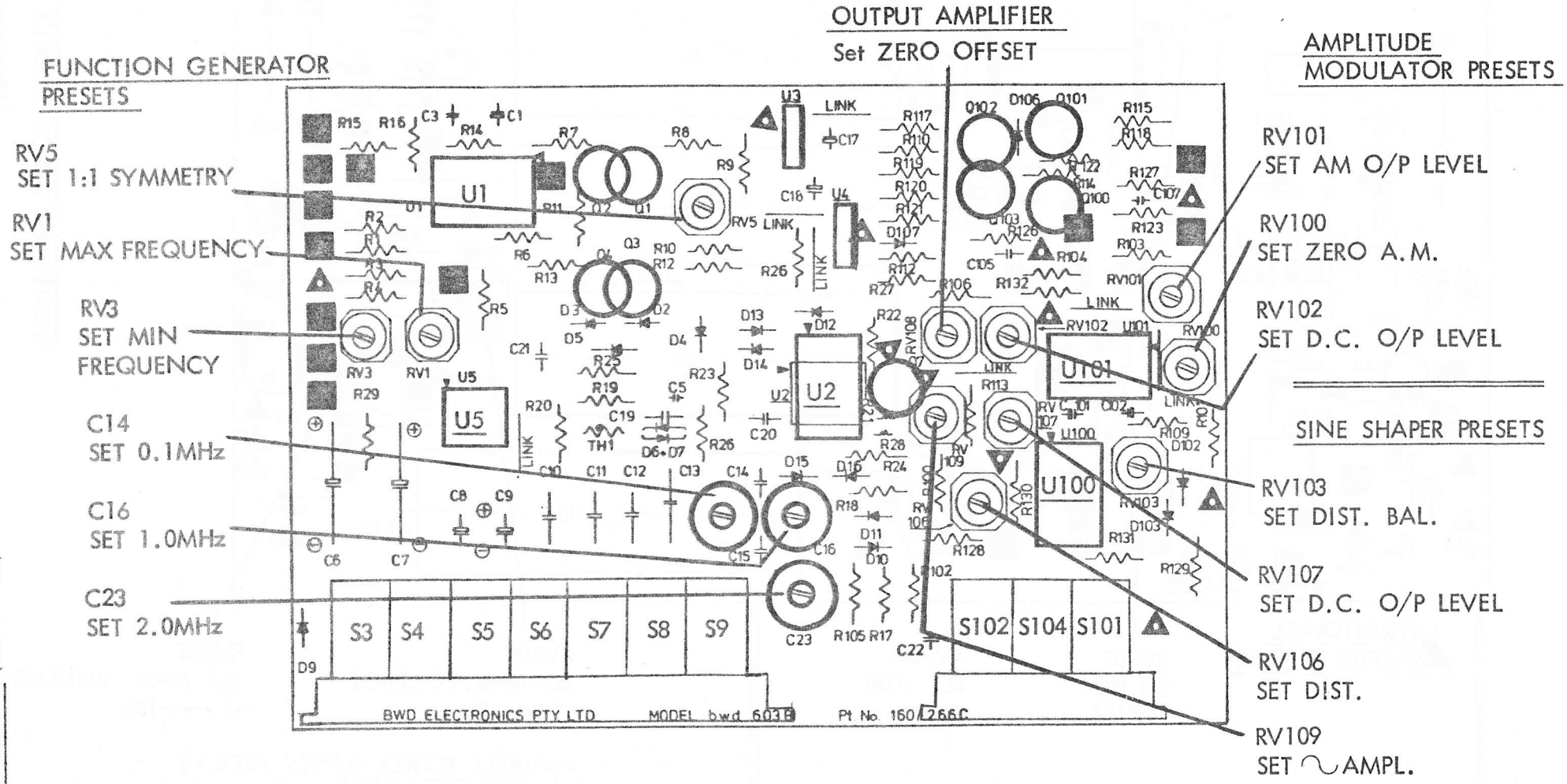
Adjust RV321 to give 15.0V indication on the voltmeter.

7.24 PRINTED CIRCUIT BOARD DRAWINGS:

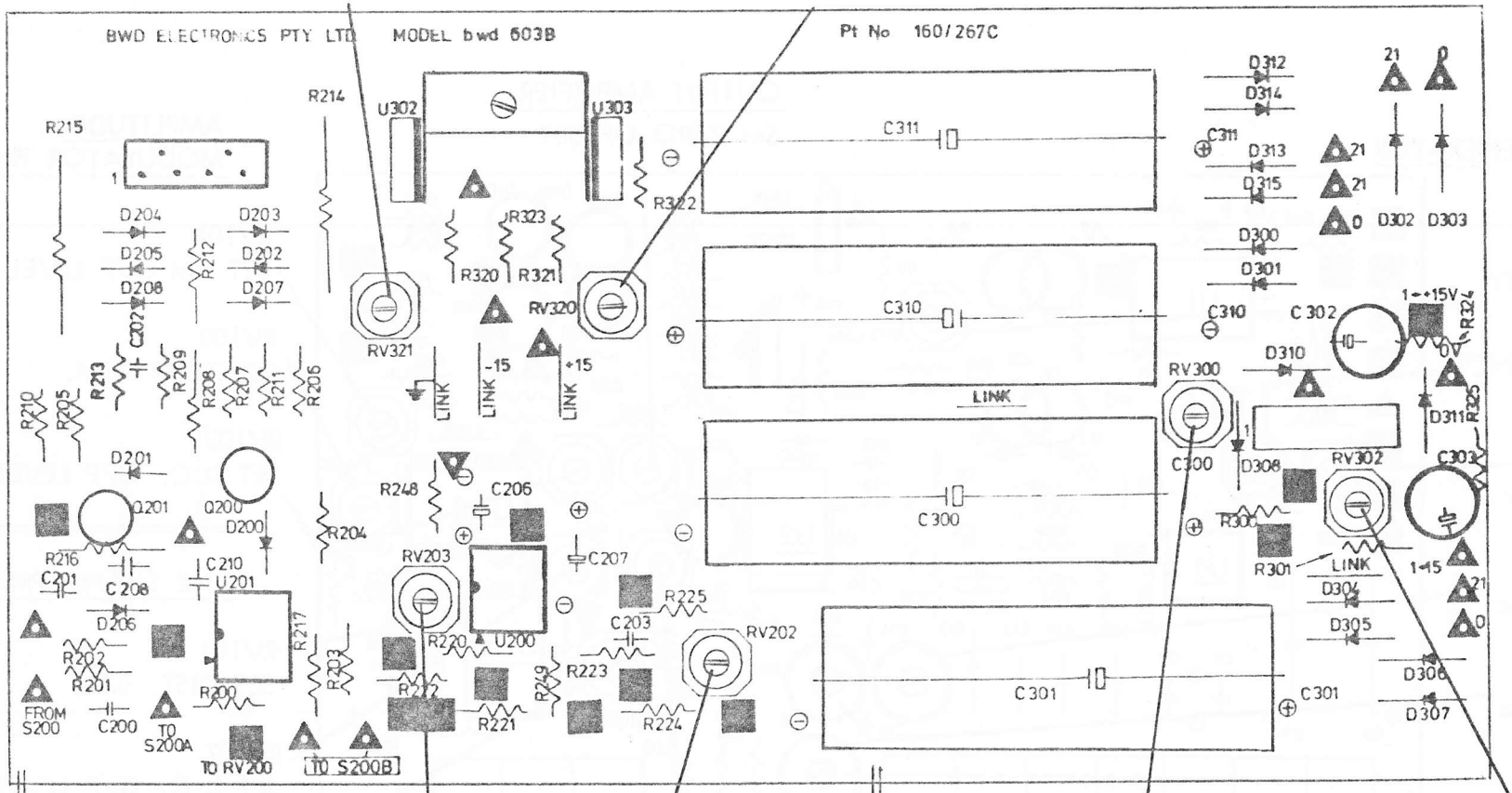




7.24 FUNCTION GENERATOR PRINTED CIRCUIT BOARD
(Viewed from the Component Side)



FIXED POWER SUPPLY PRESETS



OPERATIONAL AMPLIFIER PRESETS

RV203
Set DC OFFSET

RV202
SET x100 GAIN

RV300
SET MAX. VOLTAGE
+1 → +15V

RV302
SET MAX. VOLTAGE
-1 → -15V

VARIABLE POWER SUPPLY PRESETS

7.25 ADJUSTMENT PROCEDURE OF THE FUNCTION GENERATOR:

The Function Generator can be divided into three sections for ease of adjustment.

(a) Frequency and Symmetry controls.
(b) Sine Wave shaper controls.
(c) Amplitude Modulator controls.

Adjustment of controls in any one section will not affect the adjustment of controls in the other two sections.

FREQUENCY AND SYMMETRY CONTROLS:

Using the procedure outlined in Sections 7.3, 7.4 and 7.5 the presets can be set up in the following order. First set up RV5; since this control affects both RV1 and RV3 but is in turn not affected by either RV1 or RV3, adjustment once effected will not need to be repeated. RV1 and RV3 are then set up as described earlier. With all the frequency range buttons out and the frequency dial set to 10, C23 is adjusted to give 2.0MHz, then C16 and C14 can be set to give 1.0MHz and 100kHz respectively on the x100K and x10 K ranges.

SINE WAVE SHAPER CONTROLS:

Since adjustment of RV107 and RV109 are completely independent of any other control in this section, they may be adjusted at any time without concern for interactions. RV103 and RV106 however, interact and should be done together by first adjusting one and then the other until no further improvement can be made.

AMPLITUDE MODULATOR CONTROLS:

The order of adjustment described earlier for RV100, RV101 and RV102 should be followed, i.e. RV101 first, RV100 second and RV102 last. No further adjustment will be necessary.

NOTE: The DC offset control for the Output Amplifier may be adjusted at any time with no effect on the adjustments described in this or any other section.

7.26 ADJUSTMENT PROCEDURE OF THE POWER SUPPLIES:

The Power Supply section of Model BWD 603B can be divided into three independent sections:-

(a) 0 ► 200V Power Supply.
(b) 0 ► +15V Power Supply.
(c) 0 ► -15V Power Supply.

Since both of the low voltage supplies are independent and have only one preset each, the order of adjustment is optional. However the Regulation preset of the 200V supply can vary the setting of the Max. Voltage preset so that it may be necessary to check both settings after an adjustment.

7.27 ADJUSTMENT PROCEDURE OF THE INTERNAL POWER SUPPLIES:

The internal power supplies, + and -15V, can be adjusted via two preset controls. As both supplies are independent either one can be adjusted without affecting the other.

NOTE: If either of these supplies are altered check Section 7.2 for possible interactions in other parts of the unit.

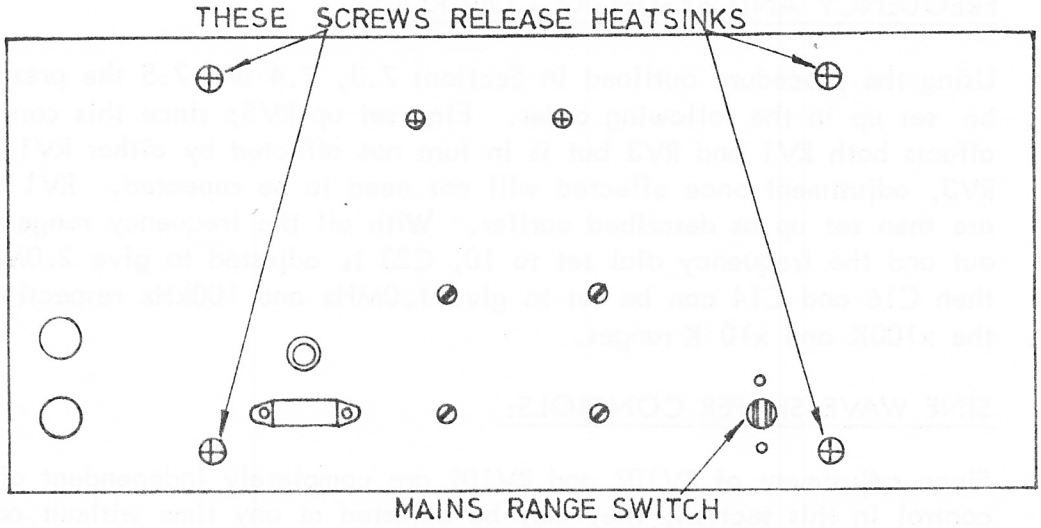


Fig. 8a. Rear Panel showing location of Heat sink securing screws.

8. MAINTENANCE:

8.1 REMOVAL OF COVERS:

(a) Top cover. With the unit in a normal operating position, i.e. with all four feet resting on a horizontal flat surface, remove the two screws securing the chromed handle end plates. Also remove the two screws located near the jointing lines of the top and bottom covers. The top cover is now free to remove.

(b) Bottom cover. With the unit inverted remove the four screws securing the plastic feet to the unit. If the top cover has not previously been removed, remove the two screws located near the jointing lines of the top and bottom covers. The bottom cover may now be removed.

NOTE: Re-assembly of the above items can be done in the reverse order of events as the removal.

8.2 REMOVAL OF HEATSINKS:

(a) The heatsinks are secured to the near panel by two screws the heads of which are visible from the rear of the unit. See fig 8A. Before removing these screws, first remove the top cover (8.1(a)) and unplug the lead(s) from the heatsink that is to be removed.

(b) The two securing screws may be removed and the heatsink will be free to move.

NOTE: Re-assembly of the heatsink can be done in the reverse order of events as the removal.

8.3 SEMICONDUCTOR REPLACEMENT:

Before removing any transistors or diodes from the unit the device should be labelled so that in the event a defective device is found, its circuit location may be identified thus isolating the source of trouble.

Should it be necessary to remove a matched pair of devices ensure that they are returned to the same point. DO NOT replace one of a matched pair, replace only with a pair obtained from the manufacturer, See Section 9.

8.4 REMOVAL OF INTEGRATED CIRCUITS:

Extreme care must be exercised in removing integrated circuits from the unit. Since all the I.C.'s are inserted in sockets a standard I.C. removal tool is recommended. However, if such a tool is not available the I.C. should be carefully pulled from its socket in such a way as not to bend or distort its pins. Similarly replacement should take place with due care ensuring that all the leads enter the socket and that no leads become bent either under the I.C. or to the side of the I.C.

8.5 REMOVAL OF COMPONENTS FROM PRINTED CIRCUIT BOARDS:

Model BWD 603B uses several single sided etched circuit boards. Care in removing components must be exercised to prolong the usefulness of the circuit board.

8.5 REMOVAL OF COMPONENTS FROM PRINTED CIRCUIT BOARDS (Cont'd)

Before attempting a repair determine, if possible, the faulty component and remove only that component. (Be sure the trouble cannot be cured by an adjustment). Turn off power before attempting removal. The first step is to clip the leads near the component, and remove the component. Then apply the soldering iron tip to the conductor side of the board at the component lead which is then removed with a straight upward motion. for large components with the leads rigidly connected, i.e. preset potentiometers, the soldering iron tip should be rotated from lead to lead while applying pressure to the component to lift it from the circuit board.

8.6 REPAIR OF PRINTED CIRCUIT BOARDS:

Generally when replacing components on a circuit board two types of damage can take place:-

(a) A conductor strip can lift from the board.
(b) A conductor strip may break.

A lifted strip may be re-cemented with a quick drying acetate cement having good electrical insulation characteristics.

A broken conductor strip may be joined by a short length of tinned copper wire. DO NOT attempt to bridge a break with solder.

8.7 REMOVAL OF FRONT PANEL CONTROLS:

This section describes the removal of all front panel rotary controls except the frequency vernier:-

(a) The knob may be removed by loosening the grub screw(s) in the side. There are two types of grub screws one requiring a 3/64" AF hexagonal key and the other requiring a 5/64" AF hexagonal key.

(b) The wires soldered to the control should now be un-soldered after making a note of their connection.

(c) Using a $\frac{1}{2}$" AF ring or tube spanner, remove the nut holding the control to the front panel.

(d) The control may now be withdrawn from the panel.

(e) Assembly is done in the reverse order.

8.8 REMOVAL OF THE FREQUENCY DIAL AND CONTROL:

(a) Loosen the grub screws(s), with a 5/64" AF hexagonal key, in the side of the knob and remove the knob.

(b) Remove the two brass screws holding the dial to the reduction drive, and take the dial off the shaft.

8.8 REMOVAL OF THE FREQUENCY DIAL AND CONTROL: (Cont'd)

(c) Inside the unit note the connection of the three wires and then unsolder them.

(d) Loosen the two grub screws holding the potentiometer shaft to the reduction drive.

(e) Remove the $\frac{1}{2}$" AF hexagonal nut nearest the front panel and withdraw the control from its mounting bracket.

9. REPLACEMENT PARTS:

9.1 Spares are normally available from the manufacturer BWD Electronics Pty. Ltd. When ordering it is necessary to indicate the model and serial number of the instrument. If exact replacements are not to hand, locally available alternatives may be used, provided they possess a specification not less than, or physical size not greater than the original components.

9.2 Many of the semiconductors in Model BWD 603B have been factory selected for the particular position they occupy. It is most important that the handbook parts list be consulted before replacing any semiconductors since selected or matched devices can be obtained ONLY from the manufacturer BWD Electronics Pty. Ltd.

9.3 As the policy of BWD Electronics Pty. Ltd. is one of continuing research and development, the Company reserves the right to supply the latest equipment and make amendments to circuits and parts without notice.

10 GUARANTEE:

The equipment is guaranteed for a period of twelve (12) months from the date of purchase against faulty materials and workmanship.

Please refer to the Guarantee Registration Card which accompanied the instrument, for full details of conditions of warranty.

12. PARTS LIST:

12.1 COMPONENT DESIGNATIONS:

A	Assembly	H	Heater	RV	Variable Resistor
B	Lamp	J	Jack (Socket)	S	Switch
C	Capacitor	L	Indicator	T	Transformer
D	Diode	M	Meter	TH	Thermistor
DL	Delay Line	P	Plug	V	Vacuum Tube
E	Misc. elec. part	Q	Transistor	VDR	Volt Dependent Resistor
F	Fuse	R	Resistor		

12.2 ABBREVIATIONS:

Amp	Ampere	MPC	Metalised Polyester Capacitor
cc	Cracked Carbon	Ne	Neon
c	Carbon	NPO	Zero temperature co-efficient
CDS	Ceramic Disc	ns	Nano-second
cer	Ceramic	p	Peak
DPST	Double Pole Single Throw	pf	Pico Farad = 10^{-12}F
DPDT	Double Pole Double Throw	preset	Internal Preset
elec	Electrolytic	PYE	Polyester
FET	Field Effect Transistor	pot	Potentiometer
HTC	High Temp. Coating	PCB	Printed Circuit Board
kHz	Kilohertz = 10^3Hz	PIV	Peak Inverse Voltage
kΩ	Kilohm = 10^3 Ω	PYS	Polystyrene
Lin	linear	p-p	Peak to Peak
Log	Logarithmic Taper	rot	Rotary
m	Milli = x10^{-3}	rms	Root Mean Squared
MHz	Mega-hertz = 10^6Hz	si	Silicon
MF	Metal Film	Ta	Tantalum
mA	Milliampere = 10^{-3}Amp	tol	Tolerance
MΩ	Megohm = 10^6 Ω	trim	Trimmer
mfr	Manufacturer	V	Volts
MO	Metal Oxide	var	Variable
MHT	Polyester/Paper Capacitor	W	Watt
		ww	Wire Wound

12.3 MANUFACTURERS ABBREVIATIONS:

AC	Allied Capacitors P/L	McM	McMurdo Aust. P/L.
AGN	A.G. Naunton & Co. P/L.	MOT	Motorola Semiconductor Inc.
AWA	Amalgamated Wireless Aust. Limited	NS	NS Electronics P/L.
		NSF	NSF Limited
BWD	BWD Electronics P/L	PH	Philips Industries Limited
E	Electrosil Limited	S	Soanar Electronics P/L
ELN	Elna Capacitors (Soanar)	Siem	Siemens Industries Limited
F	Fairchild Aust. P/L.	STE	Stettner Capacitors Limited
HW	Hurtle Webster P/L		
IRH	IRH Components P/L		

CCT REF	DESCRIPTION				Mfr or Supply	PART NO.
	RESISTORS: (FIXED AND VARIABLE)					
R300	470Ω	1/4W	5%	MF	IRH	RG 1/4
R301	470Ω	1/4W	5%	MF	IRH	RG 1/4
R320	820Ω	1/4W	5%	MF	IRH	RG 1/4
R321	220Ω	1/4W	5%	MF	IRH	RG 1/4
R322	330Ω	1/4W	5%	MF	IRH	RG 1/4
R323	330Ω	1/4W	5%	MF	IRH	RG 1/4
R324/25	680Ω	1/4W	5%	MF	IRH	RG 1/4
R326/27	680Ω	1/4W	5%	MF	IRH	RG 1/4
RV300	2KΩ	Cermet	var	preset	S	VTP
RV301	5KΩ	C. Lin	var		S	VCU
RV302	2KΩ	Cermet	var	preset	S	VTP
RV303	5KΩ	C. Lin	var		S	VCU
RV320	5KΩ	Cermet	var	preset	S	VTP
RV321	1KΩ	Cermet	var	preset	S	VTP
	CAPACITORS:					
C300	4700µF	35V		elec	ELN	TYPE RT
C301	4700µF	35V		elec	ELN	TYPE RT
C302	100µF	25V		elec	PH	2222-016-16101
C303	100µF	25V		elec	PH	2222-016-16101
C310	4700µF	35V		elec	ELN	TYPE RT
C311	4700µF	35V		elec	ELN	TYPE RT
C320	50µF	150V		elec	PH	2222-040-11509
C321	50µF	150V		elec	PH	2222-040-11509
	SEMI-CONDUCTORS:					
D300	Diode			Si		A14D
D301	Diode			Si		A14D
D302	Diode			Si		A14D
D303	Diode			Si		A14D
D304	Diode			Si		A14D
D305	Diode			Si		A14D
D306	Diode			Si		A14D
D307	Diode			Si		A14D
D308	Diode			Si		A14D
D309	Diode			Si		A14D
D310	Diode			Si		A14D
D311	Diode			Si		A14D
D312	Diode			Si		A14D
D313	Diode			Si		A14D
D314	Diode			Si		A14D
D315	Diode			Si		A14D
D320	Diode			Si		IN4004
D321	Diode			Si		IN4004
U300	3 Terminal Adjustable Regulator				NS	LM317T
U301	3 Terminal Adjustable Regulator				NS	LM317T

PARTS LIST - MODEL BWD 603B - DRAWING NO. 1355

CCT REF	DESCRIPTION	Mfr or Supply	PART NO.
	SEMI-CONDUCTORS (continued)		
U302	3 Terminal Negative Regulator	NS	LM320T-12
U303	3 Terminal Adjustable Regulator	NS	LM317T
	MISCELLANEOUS:		
B300	Neon Indicator	S	MB227
F300	Fuse 5Amp Q.B. 3AG		
F301	Fuse 5Amp Q.B. 3AG		
F302	Fuse (1Amp Delay (220V) 5 x 20mm		
	(2Amp Delay (110V) 5 x 20mm		
T300	Power Transformer (see Manual Change issue 7)	BWD	090-173-3
S300A-B	D.P.S.T. Toggle Switch	NSF	8370K8
S301A-B	D.P.D.T. Slide Switch	AWA	62556-56003-004

PARTS LIST - MODEL BWD 603B. DRAWING NO. 1356

CCT REF	DESCRIPTION				Mfr or Supply	PART NO.
	RESISTORS (FIXED AND VARIABLE)					
R200	82K	1/4W	5%	MF	IRH	RG 1/4
R201	10K	1/4W	5%	MF	IRH	RG 1/4
R202	100K	1/4W	5%	MF	IRH	RG 1/4
R203	10K	1/4W	5%	MF	IRH	RG 1/4
R204	10K	1/4W	5%	MF	IRH	RG 1/4
R205	10K	1/4W	5%	MF	IRH	RG 1/4
R206	150Ω	1/4W	5%	MF	IRH	RG 1/4
R207	22Ω	1/4W	5%	MF	IRH	RG 1/4
R208	330Ω	1W	5%	MF	IRH	RG 1
R209	22Ω	1/4W	5%	MF	IRH	RG 1/4
R210	150Ω	1/4W	5%	MF	IRH	RG 1/4
R211	47Ω	1/4W	5%	MF	IRH	RG 1
R212	470Ω	1W	5%	MF	IRH	RG 1
R213	47Ω	1/4W	5%	MF	IRH	RG 1/4
R214	0.5Ω	5W	5%	WW	HW	RG 1/4
R215	0.5Ω	5W	5%	WW	HW	RG 1/4
R216	560Ω	1W	5%	MF	IRH	RG 1
R217	20K	1/4W	5% or 2%	MF	IRH	RG 1/4
R218	1K	1/4W	5%	MF	IRH	RG 1/4
R219						
R220	10K	1/4W	5%	MF	IRH	RG 1/4
R221	10K	1/4W	5%	MF	IRH	RG 1/4
R222	10K	1/4W	5%	MF	IRH	RG 1/4
R223	10K	1/4W	5%	MF	IRH	RG 1/4
R224	470Ω	1/4W	5%	MF	IRH	RG 1/4
R225	1K5	1/4W	5%	MF	IRH	RG 1/4
R226	10M	1/4W	5% or 10%	MF	PH	VR37
R227	10M	1/4W	5% or 10%	MF	PH	VR37
R228	47Ω	1/4W	5%	MF	IRH	RG 1/4
R229						
R230						
R240	15K	6W	5% or 10%	WW		
R241	10Ω	1/4W	5%	MF	IRH	RG 1/4
R242	10Ω	1/4W	5%	MF	IRH	RG 1/4
R243	22Ω	1/4W	5%	MF	IRH	RG 1/4
R244	1K	1/4W	5%	MF	IRH	RG 1/4
R245	1K	1/4W	5%	MF	IRH	RG 1/4
R246	4K7	1/4W	5%	MF	IRH	RG 1/4
R247	270K	1/4W	5%	MF	IRH	RG 1/4
R248	220K	1/4W	5%	MF	IRH	RG 1/4
R249						
RV200	10K	C Lin	var		S	VCU
RV201	220K	C Lin	var c/w DPST switch		PH	
RV202	2K	Cermet	var	preset	S	VTP
RV203	500K	Cermet	var	preset	S	VTP
RV204	5K	Cermet	var	preset	S	VTP

PARTS LIST - MODEL BWD 603B. DRAWING NO. 1356

CCT REF	DESCRIPTION				Mfr or Supply	PART NO.
	RESISTORS (FIXED AND VARIABLE)(Cont'd)					
RV205	100K	C Lin	var		S	VCU
RV206	500K	Cermet	var		S	VTP
	CAPACITORS:					
C200	0.1µF	63V		CDS	S	TL
C201	12pF	630V	5%	CDS	S	TH
C202	.022µF	100V	10%	PYE	S	N
C203	47pF	630V	5%	CDS	S	TH
C204	1µF	200V	10%	PYE	S	N
C205	8µF	350V		elec	S	RT
C206	10µF	16V	10%	Ta	S	TAD
C207	10µF	16V	10%	Ta	S	TAD
C208	33pF	630V	5%	CDS	S	TH
C209	15pF	630V	5%	CDS	S	TH
C210	0.1µF	63V		CDS	S	TL
C211	100pF	630V	5%	CDS	S	TH
	SEMI-CONDUCTORS:					
D200	Diode			Si		IN4148
D201	Diode			Si		IN4148
D202	Diode			Si		IN4004
D203	Diode			Si		IN4004
D204	Diode			Si		IN4004
D205	Diode			Si		IN4004
D206	Diode			Si		IN4148
D207	Diode			Si		IN4004
D208	Diode			Si		IN4004
D209	Diode			Si		IN4004
D210	Diode			Si		IN4004
D211	Diode			Si		IN4004
D212	Diode			Si		IN4004
D213	Diode			Si	MOT	MR754
Q200	Transistor	NPN		Si	F	2N3642
Q201	Transistor	PNP		Si	F	2N3644
Q202	Transistor	PNP		Si	MOT	MJE2955
Q203	Transistor	NPN		Si	MOT	2N3055
Q204	Selected Transistor			Si	BWD	MJE340
Q205	Transistor	NPN		Si	PH	BC547
Q206	Selected Transistor			Si	BWD	MJE340
Q207	Selected Transistor			Si	BWD	MJE340
U200	Operational Amplifier				NS	LF351N or LF356N
U201	Operational Amplifier				NS	LM318N
	MISCELLANEOUS:					
S200A-B	3 Pos.	2 Pole	Slide switch		NSF	SM2-3
S201A-B	DPST Switch		Rear	RV201	PH	

PARTS LIST - MODEL BWD 603B. DRAWING NO. 1357

CCT REF	DESCRIPTION				Mfr or Supply	PART NO.
	RESISTORS (FIXED AND VARIABLE)					
R100	100Ω	1/4W	5%	MF	IRH	RG 1/4
R101	22K	1/4W	5%	MF	IRH	RG 1/4
R102	820Ω	1/4W	5%	MF	IRH	RG 1/4
R103	1K	1/4W	5%	MF	IRH	RG 1/4
R104	330Ω	1/4W	5%	MF	IRH	RG 1/4
R105	820Ω	1/4W	5%	MF	IRH	RG 1/4
R106	1K	1/4W	5%	MF	IRH	RG 1/4
R107	4K7	1/4W	5%	MF	IRH	RG 1/4
R108	1K	1/4W	5%	MF	IRH	RG 1/4
R109	10K	1/4W	5%	MF	IRH	RG 1/4
R110	470Ω	1/4W	5%	MF	IRH	RG 1/4
R111	22K	1/4W	5%	MF	IRH	RG 1/4
R112	2K2	1/4W	5%	MF	IRH	RG 1/4
R113	1K	1/4W	5%	MF	IRH	RG 1/4
R114	560Ω	1/4W	5%	MF	IRH	RG 1/4
R115	220Ω	1/4W	5%	MF	IRH	RG 1/4
R116	2K2	1/4W	5%	MF	IRH	RG 1/4
R117	27Ω	1/4W	5%	MF	IRH	RG 1/4
R118	10K	1/4W	5%	MF	IRH	RG 1/4
R119	4K7	1/4W	5%	MF	IRH	RG 1/4
R120	470Ω	1/4W	5%	MF	IRH	RG 1/4
R121	27Ω	1/4W	5%	MF	IRH	RG 1/4
R122	4K7	1/4W	5%	MF	IRH	RG 1/4
R123	560Ω	1/4W	5%	MF	IRH	RG 1/4
R124						
R125						
R126	560Ω	1/4W	5%	MF	IRH	RG 1/4
R127	62Ω	1/4W	2% or 5%	MF	IRH	RG 1/4
R128	1K	1/4W	5%	MF	IRH	RG 1/4
R129						
R130	100Ω	1/4W	5%	MF	IRH	RG 1/4
R131	22K	1/4W	5%	MF	IRH	RG 1/4
R132	22K	1/4W	5%	MF	IRH	RG 1/4
RV100	10K	Cermet	var	preset	S	VTP
RV101	20K	Cermet	var	preset	S	VTP
RV102	500Ω	Cermet	var	preset	S	VTP
RV103	1K	Cermet	var	preset	S	VTP
RV104	10K	C Lin	var	c/w DPST switch	IRH	
RV105						
RV106	1K	Cermet	var	preset	S	VTP
RV107	500Ω	Cermet	var	preset	S	VTP
RV108	10K	Cermet	var	preset	S	VTP
RV109	5K	Cermet	var	preset	S	VTP
RV110	2K5	C Lin	var		S	VCU

PARTS LIST - MODEL BWD 603B. DRAWING NO. 1357.

CCT REF	DESCRIPTION				Mfr or Supply	PART NO.
	CAPACITORS:					
C100						
C101	10µF	16V	10%	Ta	S	TAD
C102	10µF	16V	10%	Ta	S	TAD
C103	0.1µF	63V		CDS	S	TL
C104	0.1µF	63V		CDS	S	TL
C105	22pF	630V	5%	CDS	S	TH
C106	22pF	630V	5%	CDS	S	TH
C107	470pF	630V		CDS	S	TH
	SEMICONDUCTORS:					
D100						
D101						
D102	Diode			Si		IN4148
D103	Diode			Si		IN4148
D104						
D105						
D106	Diode			Si		IN4004
D107	Diode			Si		IN4004
Q100	Transistor		NPN	Si	PH	BC547
Q101	Transistor		NPN	Si	PH	BC547
Q102	Transistor		PNP	Si	PH	BC557
Q103	Transistor		NPN	Si	PH	BC547
U100	Variable Gain Amplifier				MOT	MC1445L
U101	Variable Gain Amplifier				MOT	MC1445L
	MISCELLANEOUS:					
S100)						
S101)	3 Section Push Button Switch				BWD	100-083-1
S102)						
S103A-B	DPDT Slide Switch				McM	1299-02-01
S104	DPST Switch Rear		RV104 (Push/Pull)			

PARTS LIST - MODEL BWD 603B. DRAWING NO. 1358.

CCT REF	DESCRIPTION				Mfr or Supply	PART NO.
	RESISTORS (FIXED AND VARIABLE)					
R1	100K	1/4W	5%	MF	IRH	RG 1/4
R2	100K	1/4W	5%	MF	IRH	RG 1/4
R3	10K	1/4W	5%	MF	IRH	RG 1/4
R4	10K	1/4W	5%	MF	IRH	RG 1/4
R5	100K	1/4W	1%	MF	IRH	RG 1/4
R6	100K	1/4W	1%	MF	IRH	RG 1/4
R7	33K	1/4W	1%	MF	IRH	RG 1/4
R8	4K7	1/4W	5%	MF	IRH	RG 1/4
R9	820Ω	1/4W	5%	MF	IRH	RG 1/4
R10	820Ω	1/4W	5%	MF	IRH	RG 1/4
R11	1K	1/4W	5%	MF	IRH	RG 1/4
R12	4K7	1/4W	5%	MF	IRH	RG 1/4
R13	33K	1/4W	1%	MF	IRH	RG 1/4
R14	10K	1/4W	5%	MF	IRH	RG 1/4
R15	150K	1/4W	5%	MF	IRH	RG 1/4
R16	100K	1/4W	5%	MF	IRH	RG 1/4
R17	820Ω	1/4W	5%	MF	IRH	RG 1/4
R18	10Ω	1/4W	5%	MF	IRH	RG 1/4
R19	3K3	1/4W	5%	MF	IRH	RG 1/4
R20	4K7	1/4W	5%	MF	IRH	RG 1/4
R21	220Ω	1/4W	5%	MF	IRH	RG 1/4
R22	330Ω	1/4W	5%	MF	IRH	RG 1/4
R23	1K	1/4W	5%	MF	IRH	RG 1/4
R24	100Ω	1/4W	5%	MF	IRH	RG 1/4
R25	10Ω	1/4W	5%	MF	IRH	RG 1/4
R26	330Ω	1/4W	5%	MF	IRH	RG 1/4
R27						
R28	220Ω	1/4W	5%	MF	IRH	RG 1/4
R29	10K	1/4W	5%	MF	IRH	RG 1/4
RV1	5K	Cermet	var	preset	S	VTP
RV2	10K	WW Lin	var	2 Watt	AGN	
RV3	5K	Cermet	var	preset	S	VTP
RV4	10K+10K	C Lin	var		S	VGU
RV5	100Ω	Cermet	var	preset	S	VTP
	CAPACITORS (FIXED AND VARIABLE)					
C1	10µF	16V	10%	Ta	S	TAD
C2						
C3	0.1µF	63V		CDS	S	TL
C4	47pF	630V	5%	CDS	S	TH
C5	1000pF	63V		CDS	S	TL
C6	470µF	6.3V		elec	PH	2222-016-13471
C7	470µF	6.3V		elec	PH	2222-016-13471
C8	100µF	3V	10%	Ta	S	TAD
C9	10µF	16V	10%	Ta	S	TAD

CCT REF	DESCRIPTION				Mfr or Supply	PART NO.
	CAPACITORS (FIXED AND VARIABLE) (continued)					
C10	1.0µF	100V	1%	PYC	Siem	MKM B32541-A1105J
C11	0.1µF	250V	1%	PYC	Siem	MKM B32541-A3104J
C12	0.01µF	250V	1%	PYC	Siem	MKM B32541-A3103J
C13	910pF	630V	5%	PYS	AC	
C14	10-40pF		var preset	Cer	STE	10S-06
C15	47pF	630V	5%	CDS	S	TH
C16	10-40pF		var preset	Cer	STE	10S-06
C17	10µF	16V		Ta	S	TAD
C18	10µF	16V		Ta	S	TAD
C19	100pF	630V	5%	CDS	S	TH
C20	0.1µF	63V		CDS	S	TL
C21	18pF	630V	5%	CDS	S	TH
C22	39pF	630V	5%	CDS	S	TH
C23	10-40pF		var preset	Cer	STE	10S-06
	SEMI-CONDUCTORS:					
D1						
D2	Diode			Si	PH	IN4148
D3	Diode			Si	PH	IN4148
D4	Diode			Si	PH	IN4148
D5	Diode			Si	PH	IN4148
D6	Diode			Si	PH	IN4148
D7	Diode			Si	PH	IN4148
D8						
D9	Diode			Si	PH	IN4148
D10	Diode			Si	PH	IN4148
D11	Diode			Si	PH	IN4148
D12	Diode			Si	PH	IN4148
D13	Diode			Si	PH	IN4148
D14	Diode			Si	PH	IN4148
D15	Diode			Si	PH	IN4148
D16	Diode			Si	PH	IN4148
Q1	Transistor		NPN	Si	PH	BC547
Q2	Transistor		PNP	Si	PH	BC557
Q3	Transistor		PNP	Si	PH	BC557
Q4	Transistor		NPN	Si	PH	BC547
Q5) Q6)	Incorporated into U5.					
Q7	Transistor		NPN	Si		2N5770
U1	Quad Operational Amplifier				NS	LM324N
U2	High Speed comparator				NS	LM360N
U3	Positive	6V	Regulator		NS	LM340T-6
U4	Negative	6V	Regulator		NS	LM320T-6
U5	Dual F.E.T.				NS	NPD8303CN

CCT REF	DESCRIPTION	Mfr or Supply	PART NO.
	MISCELLANEOUS:		
S1A-B S2 S3A-B) S4A-B)	3 Pos. 2 Pole Slide Switch	NSF	SM2-3
S5A-B) S6A-B) S7A-B) S8A-B) S9A-B)	Seven section push button switch	BWD	100-082-1
TH1	Thermistor	STC	CZ3

PARTS LIST - BWD MODEL 603B. DRAWING NO. 1383.

CCT REF	DESCRIPTION				Mfr or Supply	PART NO.
	RESISTORS (FIXED AND VARIABLE)					
R400						
R401	47K	1/4W	5%	MF	IRH	RG 1/4
R402	10K	1/4W	5%	MF	IRH	RG 1/4
R403	12K	1/4W	5%	MF	IRH	RG 1/4
R404	5K6	1/4W	5%	MF	IRH	RG 1/4
R405	1K	1/4W	5%	MF	IRH	RG 1/4
R406	10K	1/4W	5%	MF	IRH	RG 1/4
R407		1/4W	5%	MF	IRH	RG 1/4
R408		1/4W	5%	MF	IRH	RG 1/4
R409		1/4W	5%	MF	IRH	RG 1/4
R410	4K7	1/4W	5%	MF	IRH	RG 1/4
R411	1K	1/4W	5%	MF	IRH	RG 1/4
R412	560Ω	1/4W	5%	MF	IRH	RG 1/4
R413	470Ω	1/4W	5%	MF	IRH	RG 1/4
RV40	10K+10K	C lin	var	ganged	-	See RV4
	CAPACITORS:					
C401	1μF	100V	5%	PYE	Siem	MKM B32541-A1105J
C402	22μF	16V	10%	Ta	S	TAD
C403	10μF	16V	10%	Ta	S	TAD
	SEMI-CONDUCTORS:					
D400						
D401	Diode			Si	PH	IN4148
D402	Diode			Si	PH	IN4148
D403	Diode			Si	PH	IN4148
D404	Diode			Si	PH	IN4148
D405	Diode			Si		IN4004
D406	Diode			Si		IN4004
Q401	Transistor		PNP	Si	PH	BC557
U401	Quad Operational Amplifier				NS	LM324N

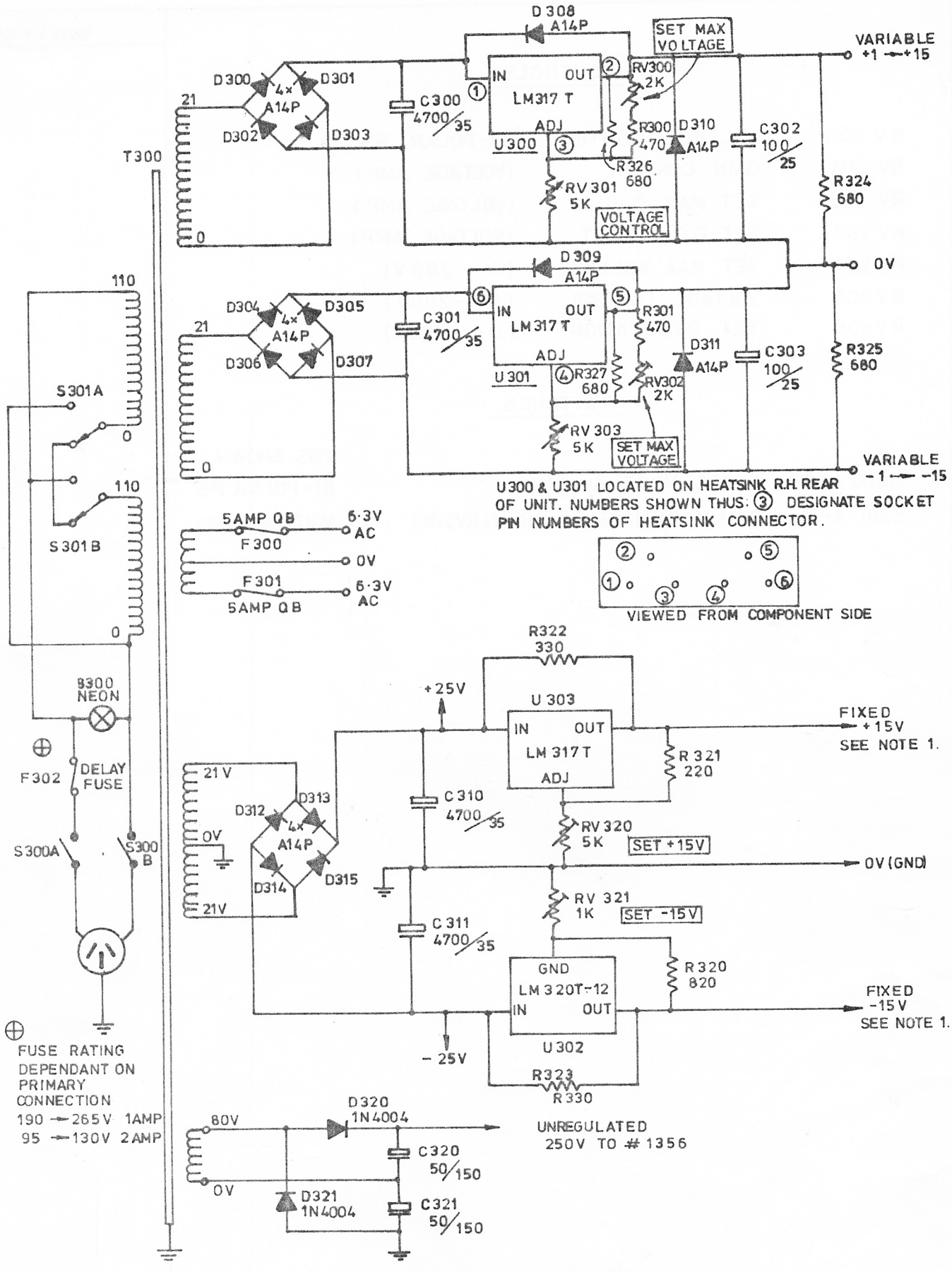
CONTROLS

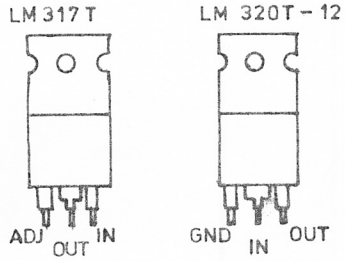
RV300	SET MAX. VOLTAGE (+1 → +15V)
RV301	VOLTAGE CONTROL (+1 → +15V)
RV302	SET MAX. VOLTAGE (-1 → -15V)
RV303	VOLTAGE CONTROL (-1 → -15V)
RV320	SET +15V (FIXED)
RV321	SET -15V (FIXED)

SWITCHES

		POS. SHOWN
S300A-B	AC. POWER ON - OFF	OFF
S301A-B	AC. POWER RANGE SELECTION	190V → 265V

WAVEFORMS





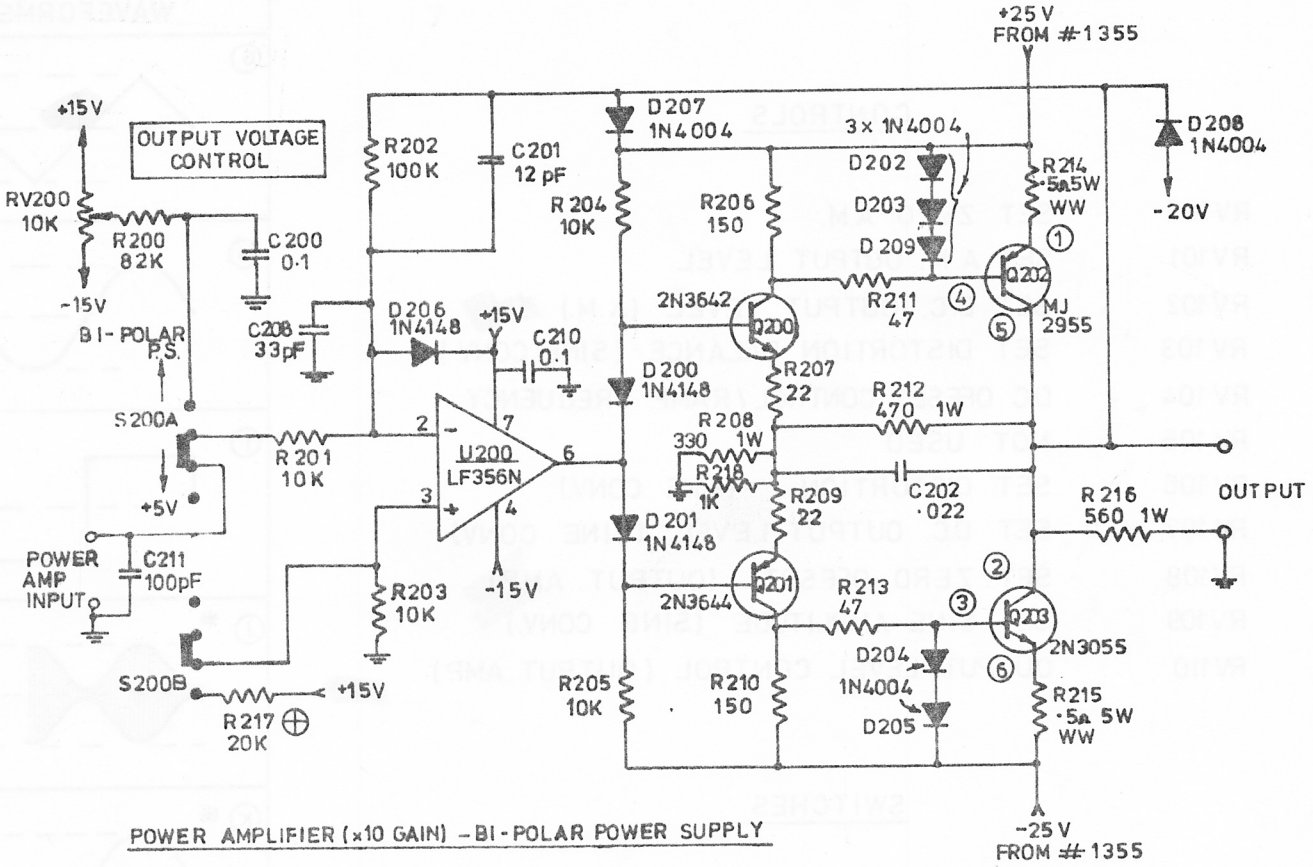
NOTE 1. THE FIXED +15V & -15V SUPPLIES ARE USED THROUGHOUT THE INSTRUMENT & ARE DESIGNATED +15V & -15V RESPECTIVELY. THEY OCCUR ON DRGS. 1356, 1357 & 1358.

CONTROLS

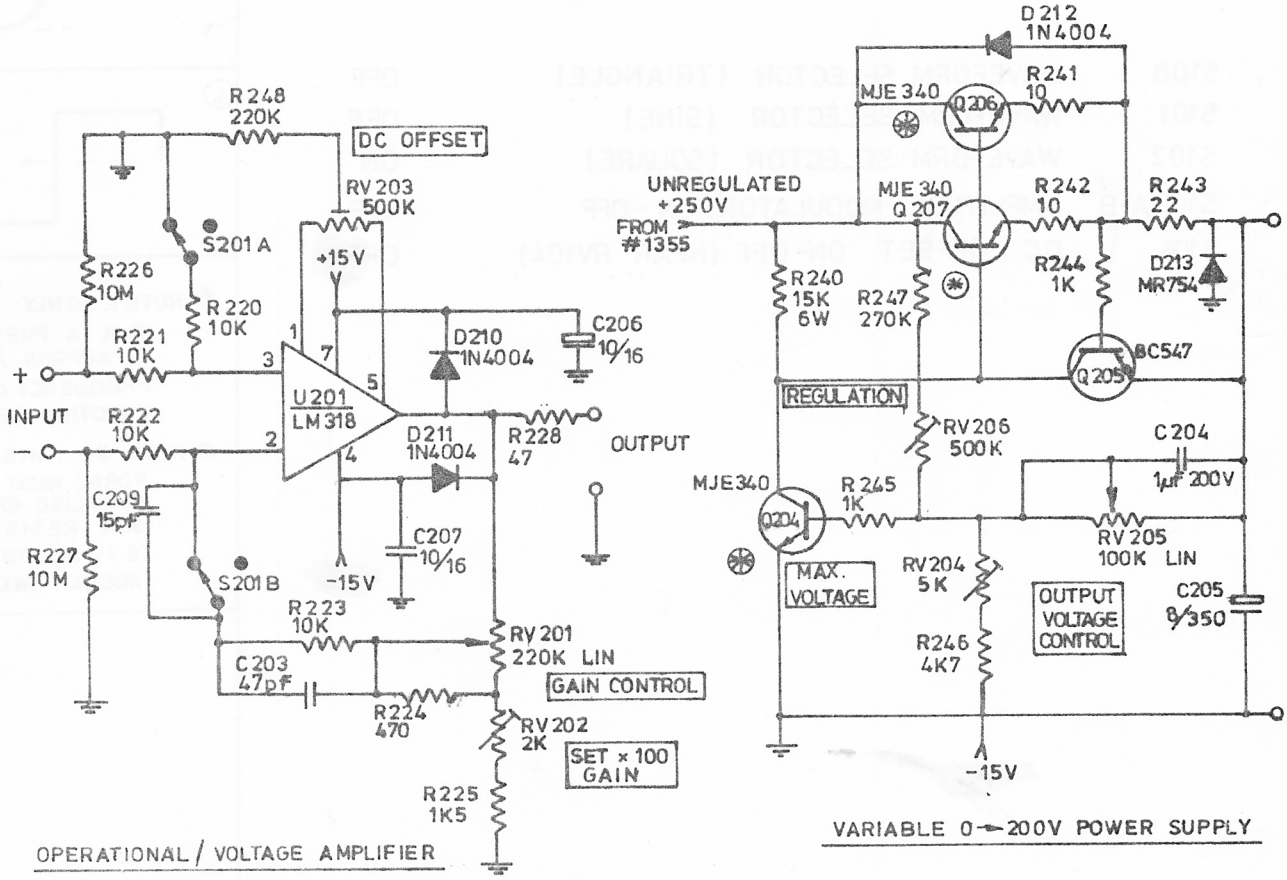
RV 200	VOLTAGE CONTROL	(BI-POLAR P.S.)
RV 201	GAIN CONTROL	(VOLTAGE AMP.)
RV 202	SET MAX. GAIN	(VOLTAGE AMP.)
RV 203	SET D.C. OFFSET	(VOLTAGE AMP.)
RV 204	SET MAX VOLTAGE	(0 → 200 V)
RV 205	VOLTAGE CONTROL	(0 → 200V)
RV 206	SET REGULATION	(0 → 200V)

SWITCHES

		POS. SHOWN
S200 A-B	P.A/P.S. MODE SWITCH	BI-POLAR P.S.
S201 A-B	OP. AMP / VOLTAGE AMP. (REAR RV201)	VOLTAGE AMP



POWER AMPLIFIER (×10 GAIN) – BI-POLAR POWER SUPPLY



✱ SELECTED ON TEST. MAY BE OMITTED.

⊕ MAY BE 2 X 10K IN SERIES

⊛ SELECTED TRANSISTOR

ALL DC SUPPLY LINES DESIGNATED EITHER +15V OR -15V ARE TAKEN FROM THE FIXED + & - 15V SUPPLIES ON DRG. No. 1355

BWD 603 B AMPLIFIERS & 200V POWER SUPPLY DRG. No. 1356 ISSUE 7

CONTROLS

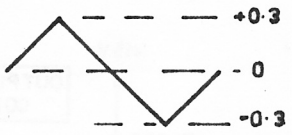
RV100	SET ZERO A.M.
RV101	SET A.M. OUTPUT LEVEL
RV102	SET D.C. OUTPUT LEVEL (A.M.)
RV103	SET DISTORTION BALANCE (SINE CONV.)
RV104	DC OFFSET CONTROL / RAMP FREQUENCY
RV105	NOT USED
RV106	SET DISTORTION (SINE CONV.)
RV107	SET D.C. OUTPUT LEVEL (SINE CONV.)
RV108	SET ZERO OFFSET (OUTPUT AMP.)
RV109	SET SINE AMPLITUDE (SINE CONV.)
RV110	OUTPUT LEVEL CONTROL (OUTPUT AMP.)

SWITCHES

		POS. SHOWN
S100	WAVEFORM SELECTOR (TRIANGLE)	OFF
S101	WAVEFORM SELECTOR (SINE)	OFF
S102	WAVEFORM SELECTOR (SQUARE)	ON
S103A-B	AMPLITUDE MODULATOR ON-OFF	OFF
S104	D.C. OFFSET ON-OFF (REAR RV104)	OFF

WAVEFORMS

Ⓖ



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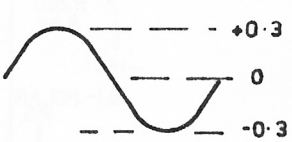
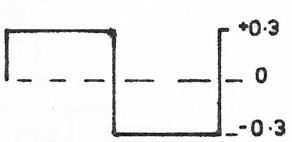
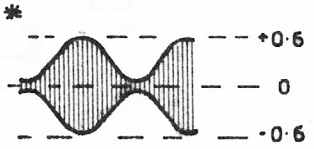


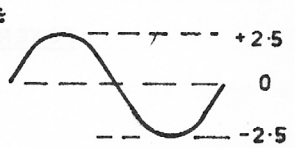
Ⓘ



Ⓙ *



Ⓚ #



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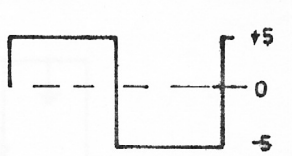
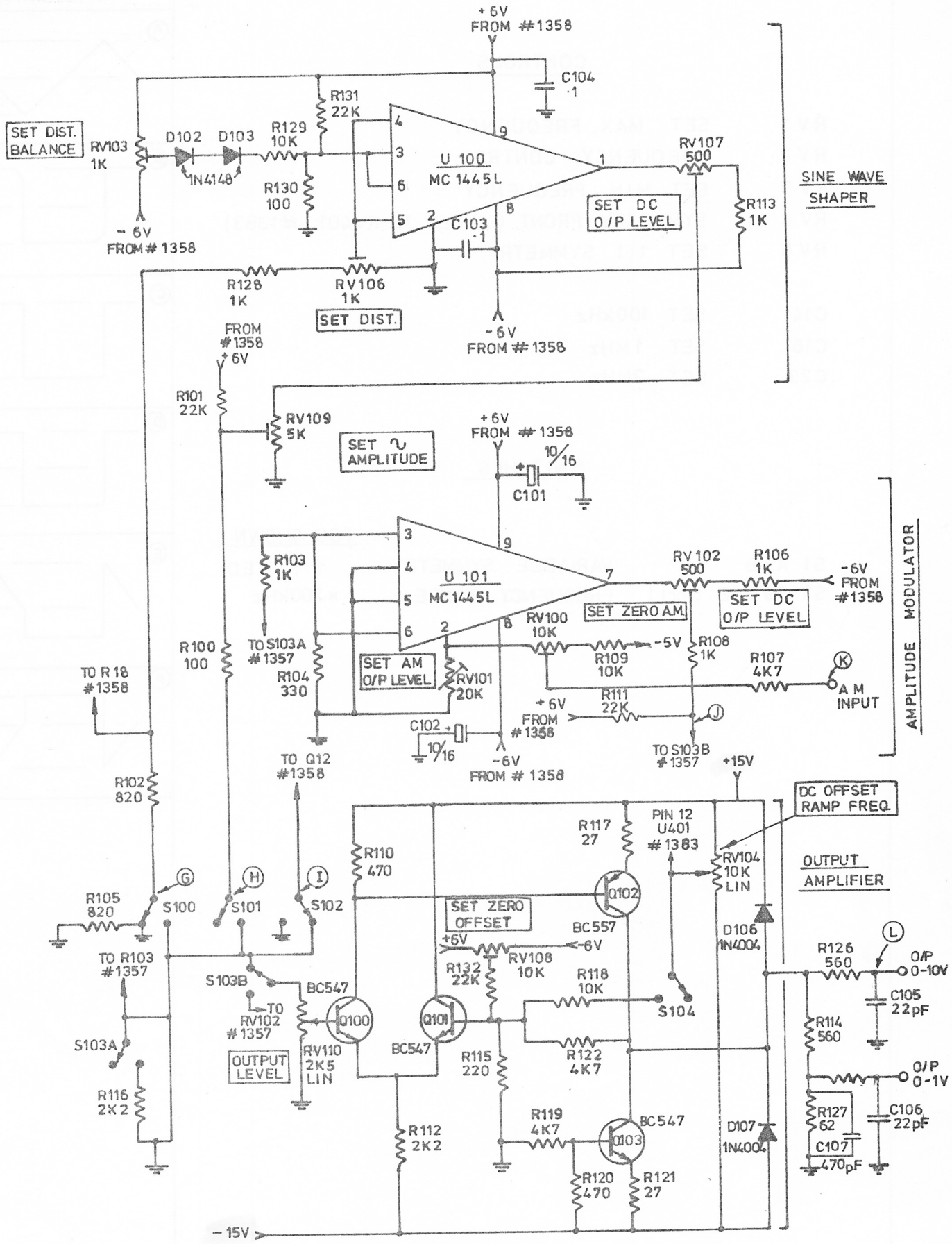


* NOTE 1: ONLY OBTAINED IF K IS PRESENT AND IS APPROX. ½th THE FREQUENCY OF THE FUNCTION GENERATOR.

\# NOTE 2 THIS WAVEFORM MUST BE SUPPLIED EXTERNALLY 39K RESISTOR FROM 6·3V AC TO AM INPUT SOCKET WILL SUFFICE.



BOTH THE +15V & −15V SUPPLY LINES ARE TAKEN FROM THE FIXED + & — SUPPLIES ON DRG. No .1355

BWD 603 B SINE SHAPER, A.M. & OUTPUT AMPLIFIER DRG. No.1357 ISSUE 7

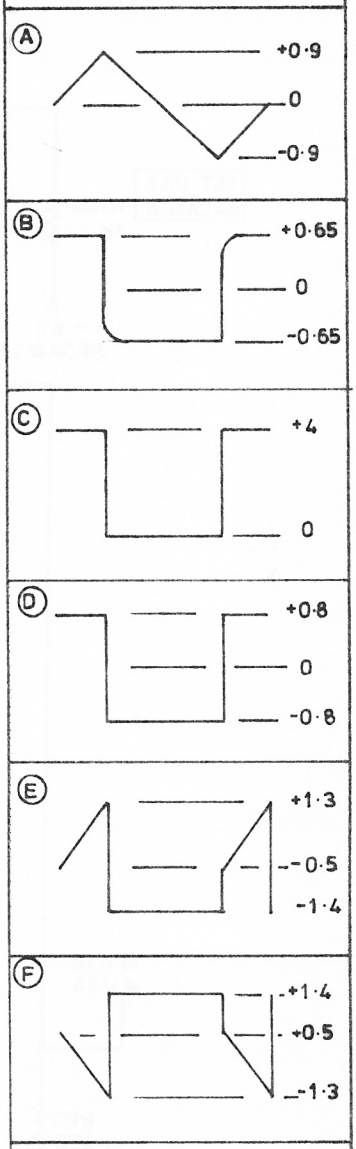
CONTROLS

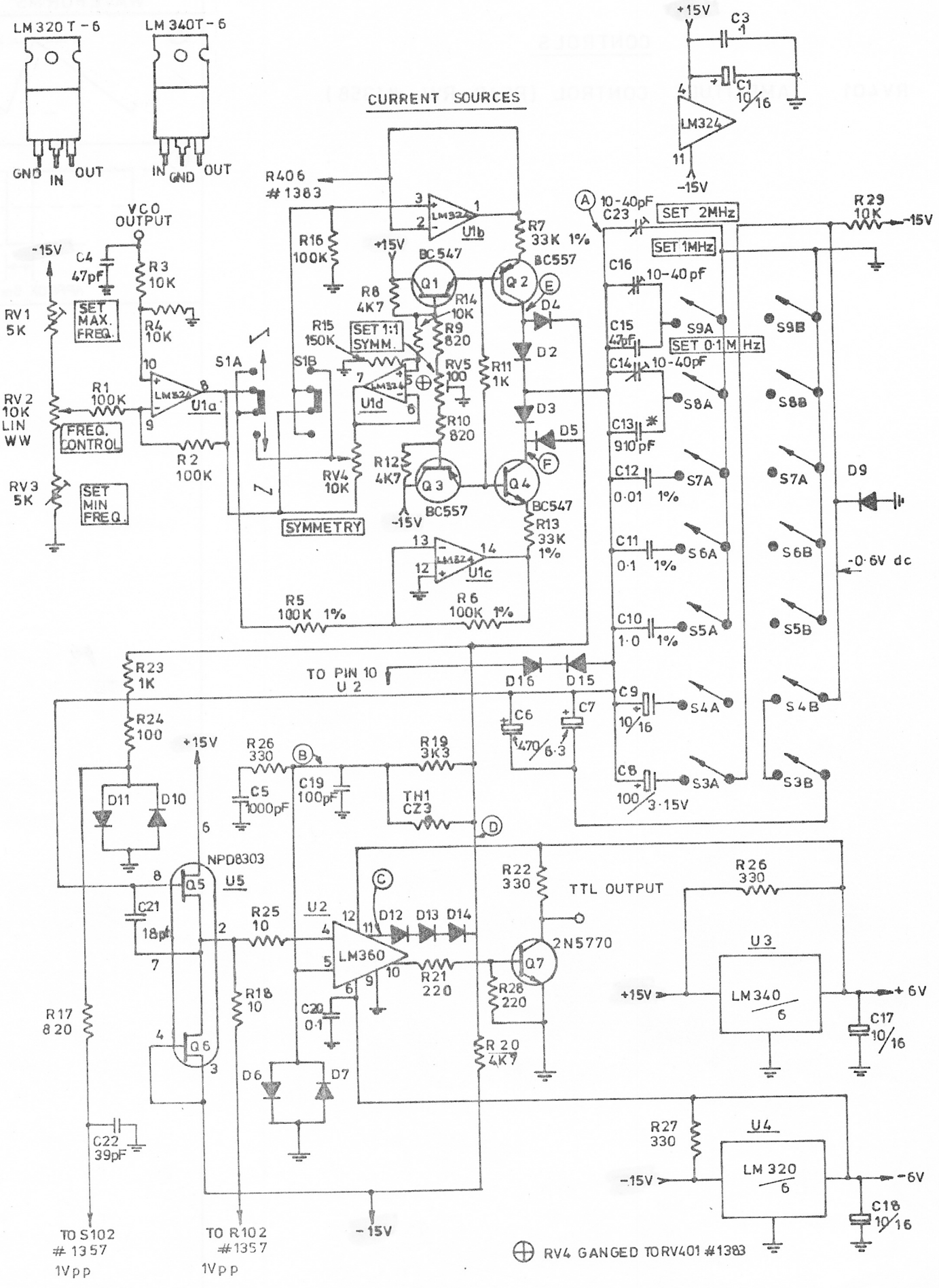
RV 1	SET MAX. FREQUENCY
RV 2	FREQUENCY CONTROL
RV 3	SET MIN. FREQUENCY
RV 4	SYMMETRY (FRONT, GANGED TO RV401 #1383)
RV 5	SET 1:1 SYMMETRY
C14	SET 100kHz
C16	SET 1MHz
C23	SET 2MHz

SWITCHES

		POS. SHOWN
S1 A-B	VARIABLE SYMMETRY	1:1 FIXED
S3-S9 A-B (incl.)	FREQUENCY RANGE	x 200kHz

WAVEFORMS





BOTH THE +15V & -15V SUPPLY LINES ARE TAKEN FROM THE FIXED + & -15V SUPPLIES ON DRG. No. 1365

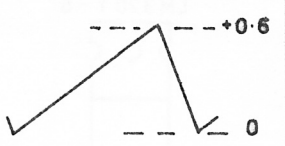
BWD 603 B TRIANGLE & SQUARE GENERATOR DRG. No. 1358 ISSUE 7

CONTROLS

RV401 AMPLITUDE CONTROL (REAR RV4 #1358)

WAVEFORMS

Ⓐ



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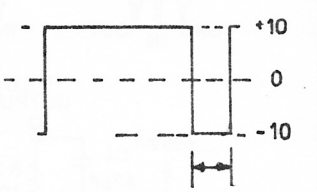
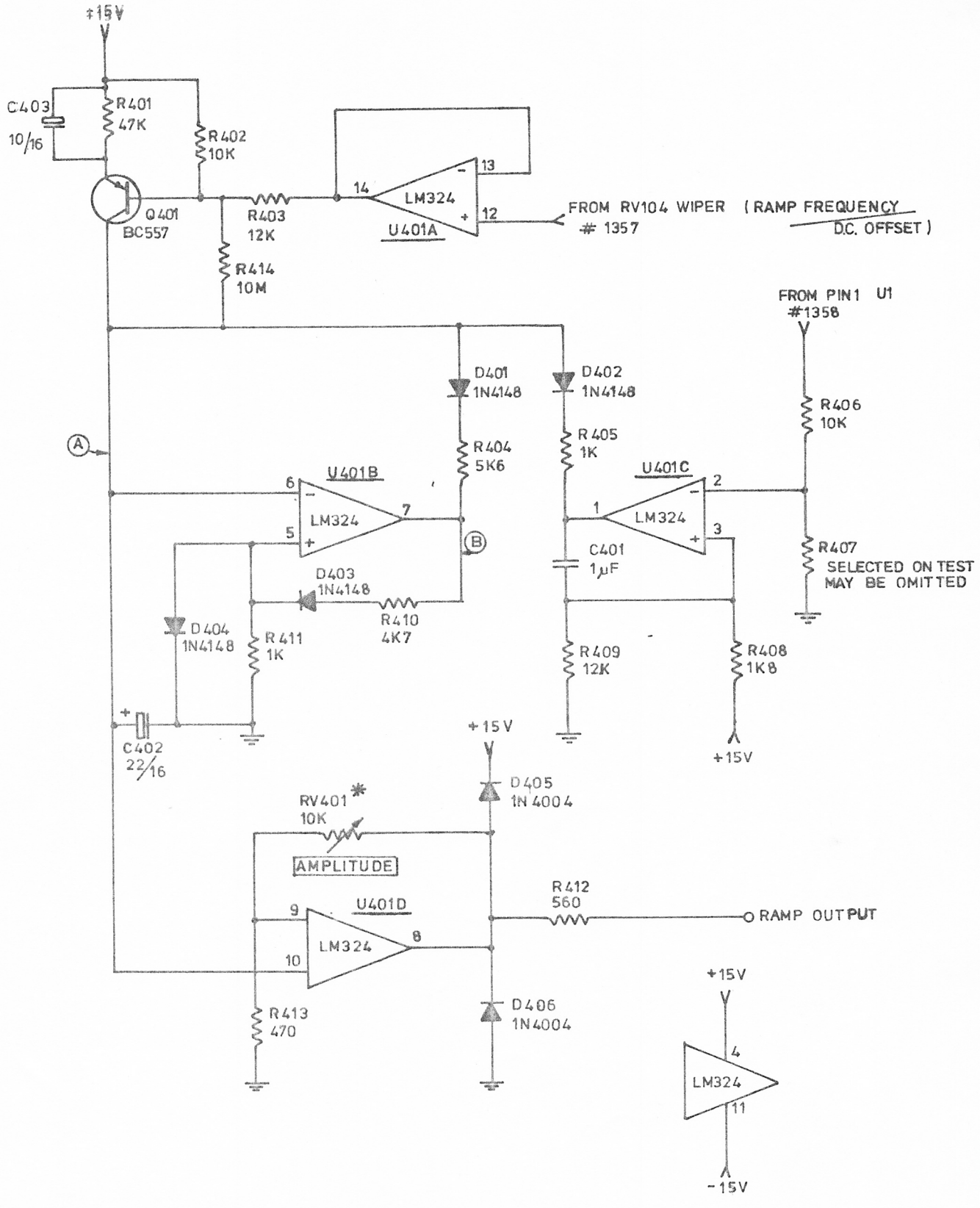
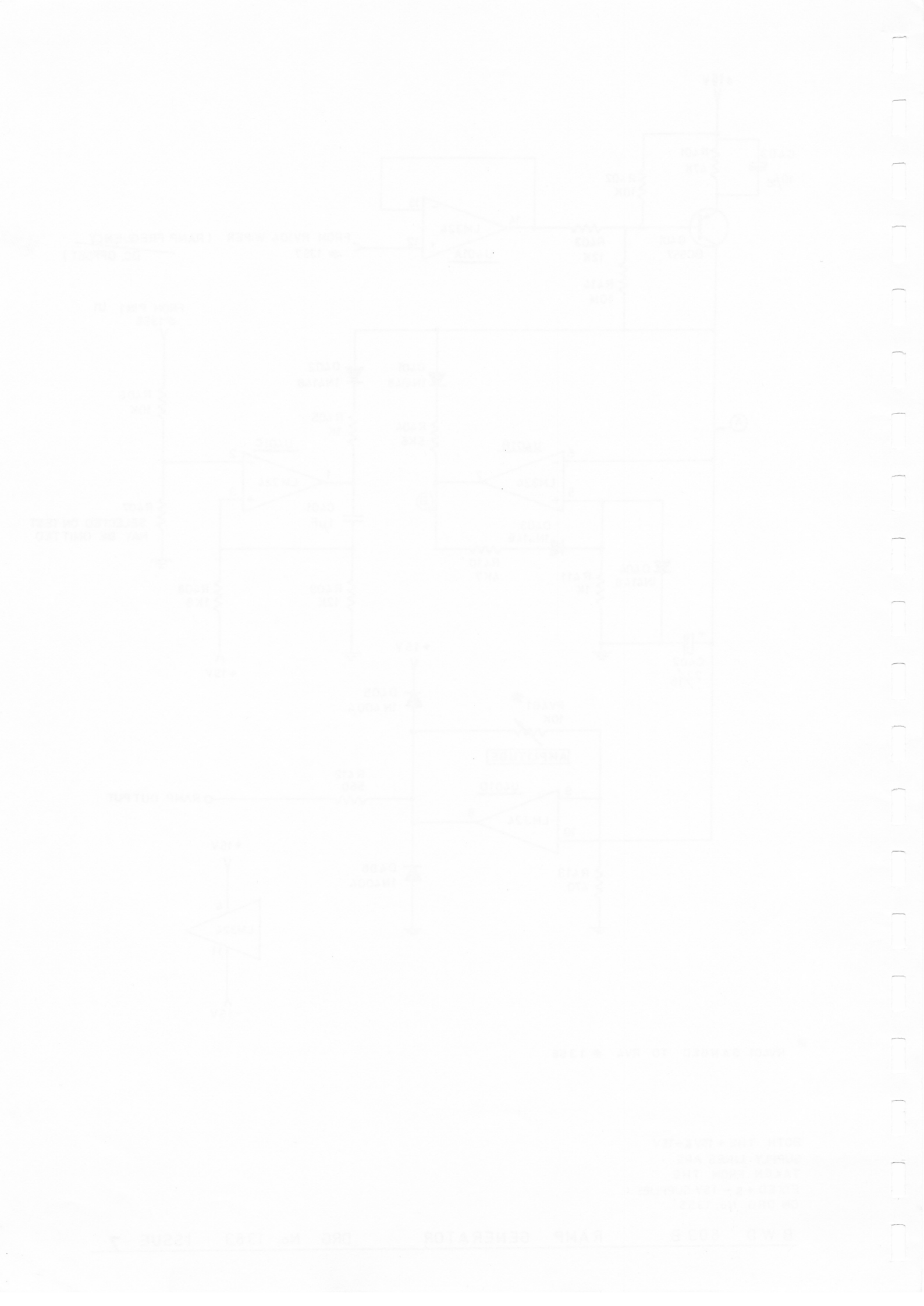




* RV401 GANGED TO RV4 # 1358

BOTH THE +15V & -15V SUPPLY LINES ARE TAKEN FROM THE FIXED + & - 15V SUPPLIES ON DRG. No. 1355



B.W.D. ELECTRONICS PTY. LTD.

MANUAL CHANGE INFORMATION FOR MODEL BWD 603B

FROM SERIAL NO.	ISSUE	DATE	FROM SERIAL NO.	ISSUE	DATE
38780	2	25.11.77	See below	7	11.2.80
38840	3	13.12.77			
39620	4	28.4.78			
39700	5	15.4.78			
44140	6	1.11.79			

Issue	Page	Sect.	Cct.	AMENDMENT
2	11-5	11	1356	C207 changed from 0.1µF to 10µF
2			1356	Q204, Q206 and Q207 changed to selected components
2	11-8	11	1358	R9 and R10 changed from 1K2 to 820Ω
2	11-9	11	1358	C22 changed from 22pF to 39pF
3	11-11	11	1383	C403 10µF 16V 10% Added.
3	7-6	7		(7.14) was:- "With the controls set as for RV103 but with an oscilloscope connected to the output terminals, set RV107 so that the average DC level remains unchanged when the Function Selector switch is changed from ⏦ to ∿ and back."
3	7-6	7		(7.16) was:- "Set the controls as shown below and connect the input of the Amplifier as shown. Adjust the level at point A to be 10V p-p. Measure the signal at point B and adjust RV202 to give 10V p-p."
4	11-4	11	1356	R208 47Ω changed to 330Ω
4	11-5	11	1356	D210 IN4004 and D211 IN4004 added
4	11-5	11	1356	U200 LM318N changed to LF356N
4	11-5	11	1356	C201 10pF changed to 12pF
5	11-4	11	1356	R207, R209 10Ω changed to 22Ω
5	11-4	11	1356	R218 1KΩ added from ⏚ to R209
5	11-5	11	1356	C211 100pF Added - Circuit error. Applicable to all issues.
6	11-5	11	1356	U200 LF356N changed to LF351N or LF356N
6	11-6	11	1357	R101 22K Added from R100 to +6V
6	11-6	11	1357	R108 1K Added in series with wiper of RV102 to S103B
6	11-6	11	1357	R111 22K Added from junction of R108 and S103B to +6V
6	2-3	2		Para 2-16 line 3 should read:- Range +2 to +15 volts and -2 to -15 volts or a single ±4 to 30 volts
7	11-3	11	-	T300 power transformer Part No. 090-173-1 applicable S/No. 38780 to 38839 Part No. 090-173-2 applicable S/No. 38840 to 44033 Part No. 090-173-3 applicable S/No. 44034 onwards For Service Serial No. 3870 to 44033 use 090-173-2 and Serial No. 44034 onwards use 090-173-3
7	5-2	5	-	Drawing error applicable all units square module should be designated 6001